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SUPPORT OF THE AIR FORCE WEATHER AGENCY'S GLOBAL THEATER WEATHER ANALYSIS AND PREDICTION SYSTEM (GTWAPS) AND CLOUD DEPICTION FORECAST SYSTEM-II (CDFS-II): A CURRENT STATUS REPORT

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1. INTRODUCTION

Advances in computational science and the field of meteorology have made possible great strides in numerical weather prediction and in specialized forecast systems designed to produce tailored weather products. Northrop Grumman Mission Systems provides the system engineering, management and sustainment support for two such specialized systems at the Air Force Weather Agency (AFWA): the Global Theater Weather Analysis and Prediction System (GTWAPS) and the Cloud Depiction and Forecast System (CDFS-II). These forecast systems provide highly specialized meteorological forecasts and precision tailored products globally to support worldwide military users in mission planning and support.

GTWAPS was described in earlier papers by Starr et al. (2000, 2001). The cornerstone of the GTWAPS system, the Penn State/NCAR Mesoscale model, MM5, is run operationally over most of the land surface of the globe with varying resolution. The GTWAPS system includes several models, which were designed to specifically meet DoD, DOT, and other federal agency's needs. Satellite data are integrated to better depict the snow cover with the Snow Depth (SNODEP) module and surface moisture and vegetative characteristics via the Agriculture Meteorological (AGRMET) module. The Land Surface Model (LSM) has enabled a better coupling of land and oceanic models for a seamless initialization of the earth's surface.

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The Cloud Depiction and Forecast System - Version II (CDFS-II) provides near real-time global cloud analysis operations at AFWA. CDFS-II integrates new science algorithms and operational infrastructure to analyze combined global-coverage data from the Defense Meteorological Satellite Program (DMSP), the Polar Operational Environmental Satellite (POES) program, and the international constellation of geostationary environmental satellites. CDFS-II combines visible and infrared data collected from multiple satellites to produce virtually seamless cloud analyses and forecasts. CDFS-II is the only operational cloud forecast system in the world to date. CDFS-II is closely linked to the Satellite Data Handling System, which provides the necessary input stream of satellite data to the CDFS-II system.

This paper provides a status on these two systems, and describes the support and infrastructure in terms of system engineering, management and sustainment of the GTWAPS and CDFS-II systems. Since clouds impact operations, intelligence, surveillance and reconnaissance platforms and sensors, accurate depiction with high temporal and spatial resolution is a necessity for military operations. System support and integration services are included in NGMS support of this unique analysis and forecast system.

2. OPERATIONAL MESOSCALE FORECASTING: CURRENT GTWAPS CONFIGURATION

Northrop Grumman Mission Systems (NGMS) is responsible for the entire life-cycle engineering of the Air Force Weather Agency's (AFWA) GTWAPS program. GTWAPS, which is known as Air Force Weather's premier system, acquires data from a variety of sources internal to AFWA and externally from other agencies, including the US Navy's Fleet Numeric Meteorology and Oceanographic Center (FNMOC), NOAA's National Center for Environmental Prediction (NCEP), and the World Meteorological Organization, and produces fine scale atmospheric modeling worldwide to support DoD missions. NGMS's successes include supporting the war in Bosnia and the

Kosovo conflict, support for both the Gulf War and Operation Iraqi Freedom, and emergency backup support to NOAA's National Center for Environmental Prediction when their system was unable to perform its mission. We have obtained excellent feedback for our efforts to maintain a system capable of producing timely, accurate high-resolution forecasts supporting combat operations and mission planning. This system of systems houses no less than six 'applications', which are models designed for very specific purposes meeting DoD, DOT, and other federal agency's needs.

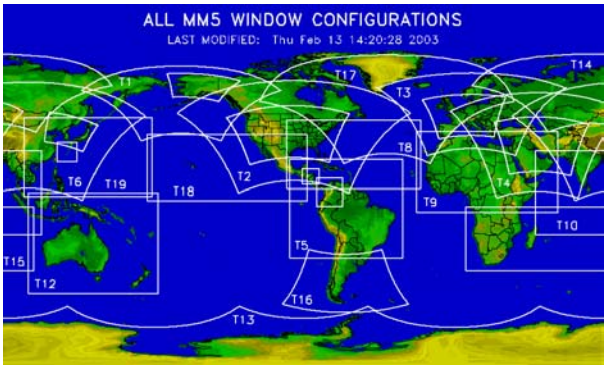


Figure 1: GTWAPS is configured to run operationally over most of the world's land area. Outer domains use a 45km mesh, inner a 15 km mesh with finer embedded grids where needed.

The conglomerate system consists of two IBM massively parallel production systems, an applications server, data server, development system, and a High Performance Gateway Node. This system boasts some of the latest computing technology housing the Regatta class nodes. In addition, this powerful system has made several appearances on the annual top 100 list of the largest systems in the world. With an aggressive acquisition history throughout its development this system has gone through three major hardware refreshes to remain on the cutting edge of technology.

In 1995 the hardware/modeling system was conceptualized to use IBM scalable parallel architecture running the Penn State University developed Mesoscale Model 5 (MM5). Over the last 8 years this system has typically had two large production systems and was re-architected to house the smaller models on an applications server, while serving incoming and outgoing data via its data server. Both production systems have individually been in the global top 100 production systems for several years and the combined system had the capacity to have been in the top 50 in the world. For several years the Community Coordinated Modeling Center (CCMC) was administered under the auspices of GTWAPS and enabled the academic, research, and DoD 'community' to test and run space models, the upcoming Weather Research and Forecast (WRF) model, and various data assimilation schemes. The Air Force Weather plan was to enable a compressed acquisition of the latest science via useful research grade code to rapidly 'operationalize' improved models. In its continuing evolution this system is taking a necessary step in the engineering of a Collateral Model Processing System (CMPS), which will ingest all standard data sets that the rest of GTWAPS ingests and provide parameterized meteorological data for specific operations. In the future, the CMPS will house the Space Weather Analysis and Forecast System (SWAFS) Parameterized Real-time Ionospheric Specification Model (PRISM). The PRISM will be replaced by the Global Assimilation of Ionospheric Measurements (GAIM) model, which is programmed to run on the CMPS also.

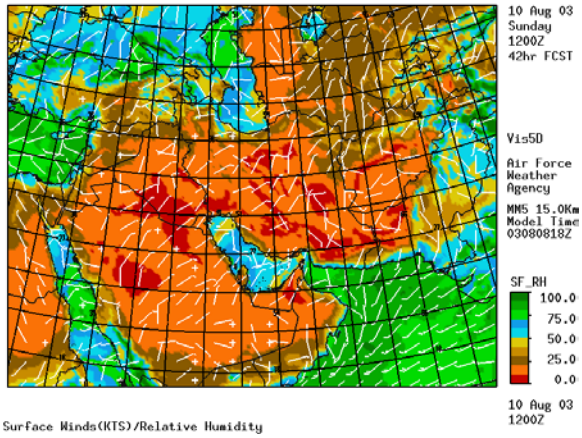
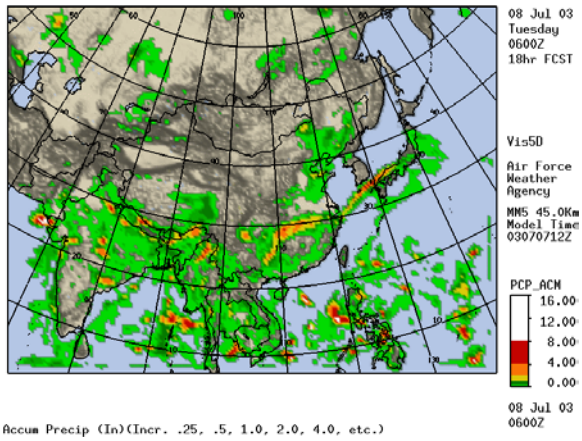


Figure 2: Operational run from MM5 domain over southwest Asia, 42 h forecast surface winds/relative humidity. Below, southeast Asia total precip, 18h forecast.



GTWAPS takes data from a variety of sources internal to AFWA and externally from other agencies,

including the Fleet Numeric Meteorology and Oceanographic Center (FNMOC), the National Center for Environmental Prediction (NCEP) and the World Meteorological Organization (WMO), and produces fine scale atmospheric modeling worldwide to support DoD missions. These "mesoscale" forecasts provide for a notable improvement over conventional synoptic scale forecast models in that they are capable of resolving and representing smaller scale features. Knowledge of the small-scale atmospheric features also improves model "initialization"—if the current state of the atmosphere is known with less error, then forecast products inherently improve. This model is run 4 times a day operationally over most of the globe. Meteorological output from this model are custom tailored to the end-user in a complex post processing system in GTWAPS.

Aside from MM5, a number of specialized models support and comprise GTWAPS and are housed on the GTWAPS Applications Server. Satellite data are integrated to better depict the snow cover with the Snow Depth (SNODEP) module and surface moisture and vegetative characteristics via the Agriculture Meteorological (AGRMET) module. The Land Surface Model (LSM) has enabled a better coupling of land and oceanic models for a seamless initialization of the earth's surface. Aside from their outright utility they are producing a better initialization of MM5 model runs, which implies improved forecasts. This system also visualizes much of its produced data with the Gridded Analysis and Display System (GRADS). A portion of SWAFS processes is run on the Applications Server to include the previously mentioned PRISM and the Ionospheric Forecast Model (IFM).

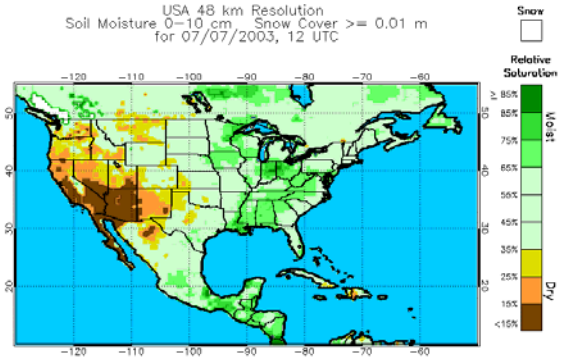


Figure 3: Soil moisture analysis, AGRMET, 07 July 2003

In order to better serve numerous customers of this data, a data trimming scheme has been adopted to remove parameters or portions of geography to tailor data sets to customer needs. This utility has allowed tailored geographical and parameterized data sets to be created and distributed to many disparate users worldwide. A novel concept in model processing employed by this system is the incremental processing and distribution of data sets. Incremental processing has permitted a greater than 50% reduction in time to get global and theater analysis and forecast data into the hands of support personnel, mission planners, and decision makers.

In the next two years, a transition from MM5 to the newer state of the art Weather Research and Forecast Model (WRF) will take place. On site research continues with the four-dimensional variational (4DVAR) assimilation scheme. This advanced technique will enable the integration of numerous 'non-standard' weather observations to be integrated into next generation physics models.

NGMS continues to perform system management and maintenance tasks with the GTWAPS program, including logistics support and systems engineering

3. WORLDWIDE CLOUD ANALYSES AND FORECASTS: SDHS/CDFS-II

Northrop Grumman Mission Systems (NGMS) currently supports the Satellite Data Handling System (SDHS) and Cloud Depiction and Forecast System II (CDFS II) through the Systems Engineering, Management and Sustainment (SEMS) umbrella in the Air Force Weather Agency (AFWA). SDHS is responsible for receiving and processing all available meteorological satellite data from national and international sources and making it available to DoD and other government users on a timely basis for daily operations and mission support, while CDFS II ingests SDHS provided data and provides near real-time global cloud analysis and forecasts using this data.

SDHS is capable of handling all current U.S. geostationary and polar orbiting satellites, and is periodically updated in order to receive new products from evolving sensors and new sources of data. SEMS is currently preparing to engineer the system to accept and process data from the next generation of geostationary and polar orbiters, including the National Polar Orbiting Environmental Sensing Satellites (NPOESS), which will eventually replace the current Defense Meteorological Satellite Program (DMSP) series at the end of their expected life spans.

In the last several months as Japan's Geostationary Meteorological Satellite (GMS) suddenly became non-operational, several US federal agencies were involved in a complex operation to provide similar data coverage until Japan could launch its next generation satellite,

MTSAT. The SDHS and CDFS II systems required complex software changes with a significant amount of inter-program communication and cooperation to provide continuous operational support and this was accomplished quite successfully.

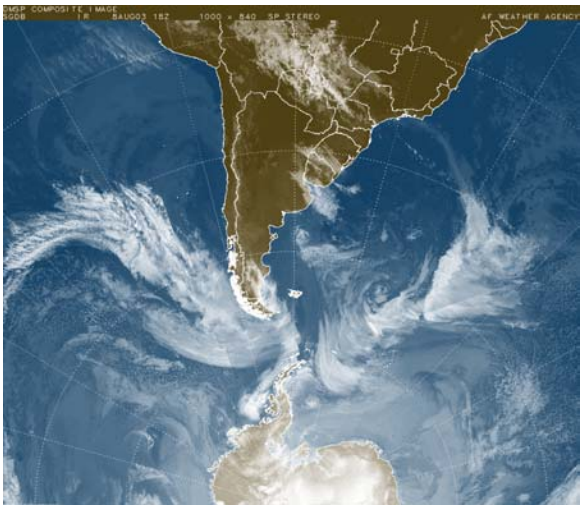


Figure 4: Visible satellite image of South America and Antarctica, processed from SDHS.

These two systems will again be put to the test in the next 12 months as the METEOSAT Second Generation (MSG) European satellites are launched and become operational.

The back end processing and visualization of SDHS received data is performed on CDFS II. This complex system significantly upgraded the operational global cloud analysis and forecasting capabilities of the United States Air Force. CDFS II provides near real-time global cloud analysis operations at AFWA. CDFS-II integrates new science algorithms and operational infrastructure to analyze combined global-coverage data from the Defense Meteorological Satellite Program (DMSP), the civilian Polar Operational Environmental Satellite (POES) program, and the international constellation of geostationary environmental satellites operated by the United States, Europe, Japan, and other foreign entities.

While AER developed the original CDFS II science algorithms and leads the Science IPT, NGMS oversees the systems engineering, management and sustainment of the CDFS II system. CDFS II processes data from a variety of satellites hourly to produce high-resolution cloud products. These cloud products provide mission planners a complete picture of the battle space from the ground to the upper atmosphere. CDFS II combines visible and infrared data collected from polar-orbiting and geostationary satellites to produce virtually seamless cloud analyses and forecasts. These data are also combined to produce continental scale water vapor and multispectral images.

The primary product of this system is the World Wide Merged Cloud Analysis (WWMCA), produced on an hourly basis. Cloud data from polar orbiting satellites (NOAA and DMSP) and geostationary satellites (GOES, METEOSAT, and previously GMS) are merged together to form a global cloud analysis. Additional parameters such as cloud amount, tops, bases, heights, and type are generated from this data.

CDFS II receives numerical and specialized model data from the Global Theater Weather Analysis and Prediction System (GTWAPS) within AFWA and uses this data to statistically parameterize the analysis, cloud classification, and forecast in the generation of the WWMCA. The SNODEP (Snow Depth) and AGRMET (Agricultural Meteorology) modules housed on GTWAPS provide significant input into the CDFS II surface temperature analysis and forecast with SNODEP providing the snow/no snow flag for the cloud detection algorithm.

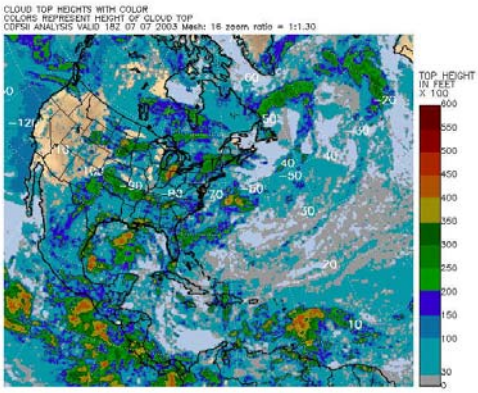


Figure 5: Sample output from World Wide Merged Cloud Analysis (WWMCA), over North America, showing cloud top heights.

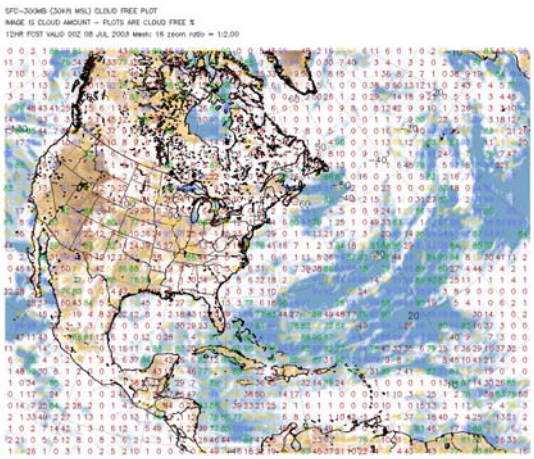


Figure 6: Sample CDFS-II output product showing cloud free amount and cloud free percentage over the North American continent

GTWAPS provided relative humidity and trajectory data contribute to the cloud forecasts run on CDFS II. Global numerical model data provides the vertical temperature profile, which enables CDFS II to determine cloud type and mean sea level height.

These parameterized data along with the WWMCA and forecast enable DoD planners and decision makers to use weather to advantage rather than 'cope and avoid'. The proper assessment, of meteorological parameters and their impact on operations and weapons systems, aids in using the weather for battle. Since clouds impact operations, intelligence, surveillance and reconnaissance platforms and sensors, accurate depiction with high temporal and spatial resolution is a necessity for military operations. System support and integration services are included in NGMS support of this unique analysis and forecast system.

4. SUMMARY

The AFWA weather production systems are one of the largest integrated computer systems in the world dedicated to assimilating, processing and distributing meteorological data having global coverage. Currently, advances in numerical modeling are being assimilated with the adoption of the Weather Research and Forecasting (WRF) model. Techniques such as reliance on TrimGRIB file generation results in an improvement in the data timeliness to end users.
Specialized models are integrated into the GTWAPS system to produce tailored products, and improve model initialization.

Parallel to these developments are those related to the processing of satellite data through SDHS, and the cloud analyses and forecasts generated with CDFS-II. Currently, CDFS-II is the only forecast system dedicated to producing cloud type and height forecasts in the world. The system has global coverage, and is fully operational providing information to units in the field, Combat Weather Teams, Operational Weather Squadrons, and mission planners.

All of these systems are currently maintained under SEMS, Northrop Grumman Mission Systems providing the role as lead on this effort, with several subcontractors assuming key roles. Because of the interdependency between these modeling systems, data sources, and resources, it is important to view these component systems as an enterprise. The enterprise wide view that SEMS takes toward sustaining and evolving these systems is critical in assuring that technological advances in science, communications, and information technology are addressed and assimilated into the evolution of these key forecast systems. As mesoscale modeling moves to increasingly complex physics, initialization and data assimilation techniques, and the next generation of weather satellite (NPOESS, GOES-R) provided sounding data increases by a factor of between one and two orders of magnitude, it is imperative we must be in the forefront in information technology and system integration. The end result of these changes include improvement in analyses and forecast products, in the number of products we provide the end user, and the timeliness and detail of the information available to the mission planner and warfighter.

5. REFERENCES

Starr, K.M., M.D. Kaufman and S.L. Flagg, 2001: Integrating Weather Modeling Capabilities for the Air Force Weather Agency: Community Coordinated Modeling Center (CCMC). *17th AMS Conference on IIPS*, Albuquerque, NM (Jan 2001).

Starr, K. et al., 2000: Status of the Global Theater Weather Analysis and Prediction System (GTWAPS). Preprints, 16th International Conference on IIPS for Meteorology, Oceanography and Hydrology, AMS Dallas, TX.