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NOWCAST FOR THE NEXT GENERATION NAVY: RECENT PROGRESS IN NAVAL NOWCAST TECHNOLOGY

Ms. Jennifer Strahl
Science Applications International Corporation (SAIC), Monterey, CA

Mr. John Cook, Dr. Paul Harasti, Mr. Gary Love, Mr. Larry Phegley, Dr. Ted Tsui, Dr. Qingyun Zhao
Naval Research Laboratory (NRL), Monterey, CA

Mr. Francisco Franco, Mr. Michael Frost, Mr. Dan Martinez, Mr. Sean Wells
Computer Sciences Corporation (CSC), Monterey, CA

Dr. John McCarthy
Aviation Weather Associates, Palm Desert, CA

1. INTRODUCTION

The battlegroup of today has limited capabilities in sampling the battlespace environment, fusing the available information, and sharing among its components a common picture of the relevant environment. This lack of comprehensive weather intelligence results in increased risk to the warfighter, failed missions, missed targets, and significant financial loss. Thus, the state-of-the-art for the assessment of battlespace environmental conditions is advancing from an infrequent, single-station perspective to a 4-D awareness by continuous fusion of multi-source observations and on-scene short-term mesoscale model predictions. Meteorological information in the 0-2h ("nowcast") timeframe is critical to tactical decision-making within the battlegroup, and until now, observations and real-time mesoscale forecasts have not been effectively bridged for Naval interests. NOWCAST for the Next Generation Navy, together with the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS™) – On Scene (COAMPS-OS™) at theater centers and shipboard, compose the on-scene, tactical-scale tier of the Naval Research Laboratory's (NRL) telescoping strategy for mission success. These projects have been developed to deliver necessary environmental information directly to the battlegroup to mitigate the risk associated with the absence of such integrated high-resolution data.

A major warfighter concern is the establishment of an information network through concepts such as the Common Relevant Operational Picture (CROP). The CROP comprises a near real-time situational awareness of all forces on the battlefield, a network of data-sharing among all relevant agencies, decision-makers, warfighters, and applications, interoperability among forces, and an advancement in the speed at which information is gathered and distributed on the battlefield. In response to this need for complete environmental awareness, NOWCAST will be deployed along with COAMPS-OS. The NOWCAST system is designed to gather and fuse all available data (observed and modeled), rapidly update the user to continuously provide a very-high resolution depiction of the current weather situation, and provide the end-user with appropriate and useful products.

NOWCAST is undergoing continual development. Improvements have been made recently to the user interface and products, including more refined satellite imagery through the use of translucency on the product overlays. New products have been designed in response to the acquisition and processing of NEXRAD Level II and III data – mosaic products have now been supplemented with individual radar plots, laying the foundation for processing on-scene tactical weather radar such as SPY-1 shipboard radar. Improved quality assurance techniques using innovation vectors are also being implemented, and verification statistics are being archived.

2. NOWCAST FOR THE NEXT GENERATION NAVY

The groundwork for NOWCAST began in 1998 while forward-deployed mesoscale data assimilation was established at Navy regional Meteorology and Oceanography (METOC) centers. A year later, the NOWCAST architecture, design elements, and communication requirements were documented, and a prototype system was begun.

In 2002, an operational prototype was implemented concurrently with COAMPS-OS at the Joint Task Force Commander's West Coast forecasting center, stationed at the Naval Pacific Meteorology and Oceanography Center – San Diego (NPMOC-SD), for use in Fleet Battle Experiment Juliet (FBE-J). FBE-J was the Naval component of the US Joint Forces Command Millennium Challenge 02 (MC02) experiment, in which live and simulated exercises engaged recent technological innovations to support the various experiment initiatives. Initial reports from users indicate that NOWCAST provided remote users with

* *Corresponding author address:* Jennifer L.S. Strahl, Science Applications International Corporation, 550 Camino El Estero, Monterey, CA 93940; e-mail: jennifer.l.strahl@saic.com

unprecedented access to radar reflectivity, cloud cover, and high-resolution surface winds, at a 5-minute refresh rate. High-resolution NOWCAST and COAMPS-OS forecasts and analyses filled the voids left by sparse, irregular, and previously unassimilated observations throughout the battlespace.

COAMPS-OS provides background model fields and hourly analyses for NOWCAST artificial intelligence algorithms currently under development; the algorithms blend these first-guess fields with observations gathered from the battlegroup and beyond, and perform real-time verification. The resulting database is rapidly updated, on the order of 5-60 min, and products are delivered to end users throughout the battlegroup via web-based client/server technology. Products are derived from the fused data, and they can be easily tailored to the needs of either warfighters or METOC personnel using the NOWCAST Java web interface.

2.1 Four-Tier Architecture

The client-server framework of NOWCAST enables all remote users on the network equal and adaptable access to all available environmental information residing in a central database. Fig. 1 is a schematic diagram of NOWCAST components. The system architecture follows a four-tier Internet design. The user directly interfaces with Tier 1, the client web browser and Nowcast applet. Tier 2 is the secure HTTP server, Java servlet engine, IRC server, and LDAP database. Tier 3 comprises the real-time, on-demand product generation, data fusion, and automated quality control. Raw data production and a database compose Tier 4.

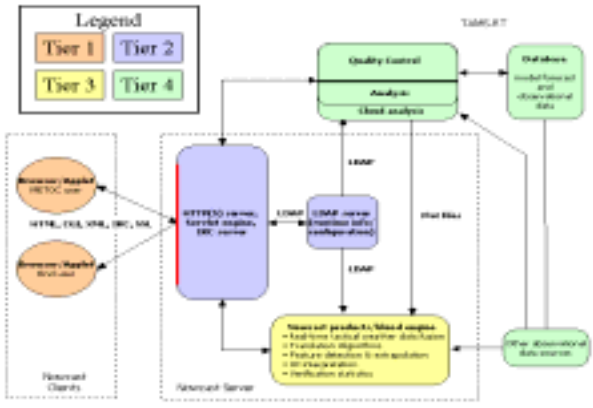

Fig. 1. Nowcast architecture showing four-tier design (from Cook et al., 2000).

2.1.1 Tier 1

Fig. 2 shows a screen shot of the NOWCAST Java applet. The applet is launched through a login web page from any web browser on the network. Users can customize folders of product "tabs" based on their specific operational tasks. To create an individual product tab, the region of interest is selected from a global map, and then products are chosen for display as shown in Figure 2. Up to two products may be displayed on a given tab, and these product images are displayed in geo-registered layers on top of a background map. Each element of the plot may be toggled on or off, including the background topography, reference lines, political or other significant boundaries, and the meteorological products themselves. Interactivity is permitted, including zooming, data interrogation, looping, creation of time series, overlay toggling, units switching, and tab manipulation. Displayed products are automatically updated in real time. For products that comprise a data volume, a vertical slider bar appears in the product column to the right of the image. The user may slide the indicator up and down to interrogate horizontal slices of the data, as shown in Figure 3.

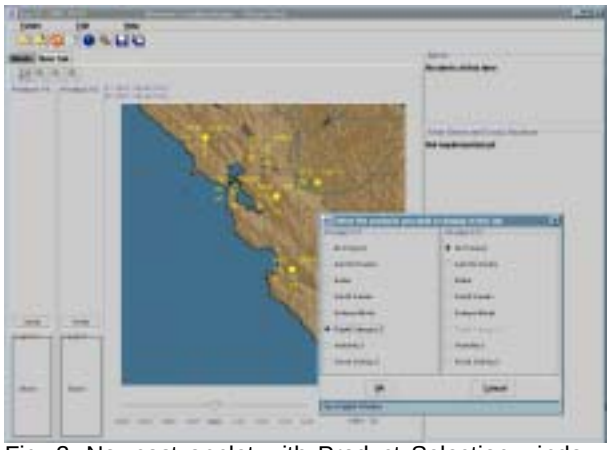

Fig. 2. Nowcast applet with Product Selection window for a new tab.

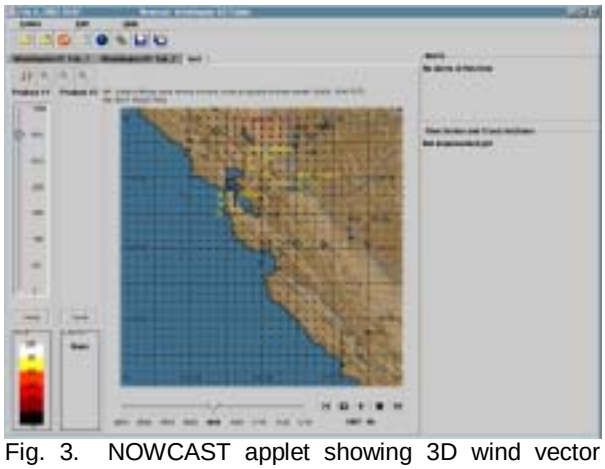

Fig. 3. NOWCAST applet showing 3D wind vector product interrogated with vertical slider.

2.1.2 Tier 2

The servers of Tier 2 communicate with the Tier 1 interface to provide the user with requested information as well as to push information to the user. Products in the open folder are continually refreshed as more recent data and products are made available by Tier 3 processes. Alerts based on configurable thresholds can be broadcast to the users of a particular folder. The components of this tier manage the users' configuration, runtime information, and login/authentication. Chat capabilities will allow warfighters to consult local METOC experts and conduct discussions with other users in the future.

2.1.3 Tier 3

Products are generated through data fusion processes in Tier 3. Data processed in Tier 4 are fused through various algorithms; products are derived from these data and pushed to the user through Tier 2. All products are created with available observations or analyses, and certain parameters are extrapolated in to short-term forecasts (nowcasts) verifying over the subsequent 2h. Feature detection algorithms will be incorporated along with model first-guess information to improve these nowcast fields. A unique feature of NOWCAST products is an end-user confidence level that is computed with each product update. When a new product is created, the old product is verified using available data at the valid time. This information is archived, and the trends are used to give the end-user some indication of the confidence of the current product.

2.1.4 Data Processing Elements

ADAS – Advanced Regional Prediction System (ARPS) Data Assimilation System has been adapted into NOWCAST. ADAS fuses satellite and radar data with observations onto model background fields for improved hourly three-dimensional cloud and moisture fields, with future feedback into mesoscale models for initialization.

National Center for Atmospheric Research (NCAR) Ceiling and Visibility Algorithm – Fuzzy logic blending model fields, satellite data, surface observations, and upper-air reports and forecasts has yielded improved ceiling and visibility products.

Radar – 10-min nationwide composites of Level III NEXRAD reflectivity data have been developed and implemented. Single-station level II data are accessed via the CRAFT project. Efforts are underway to acquire radar data from non-CONUS sources. Progress is being made using 3.5DVAR data assimilation to incorporate Doppler wind information into NOWCAST. Joint efforts with NCAR and the University of Oklahoma have produced more quality control processing, with intentions to include shipboard tactical radar data for meteorological use.

Satellite – Satellite data are processed through Terascan on a separate server. Raw fields are stored in Tier 4 and are enhanced and rendered as imagery in Tier 3. For more information on the NRLSAT data retrieval process, refer to Geiszler et al 2003, in this preprint.

Observations – Varied observations, including METARs, rawinsondes, shipboard reports, aircraft (manned/unmanned) reports, and buoy data, are integrated into NOWCAST. Observing station reports are treated as an overlay within the applet. Lightning data from commercial providers are available within NOWCAST. If selected as a data overlay within the applet, lightning data are pushed to the applet as they arrive in Tier 4. They, too, are treated as a product overlay and can be coupled with a variety of other products.

Quality Assurance – Users can obtain product-specific verification of analyses against observation, with drill-down capability from a given region to an individual station history. Some feature-based monitoring has been incorporated through the computation of leads and lags in certain fields. Quick-look confidence intervals are available for a variety of fields and supplement other traditional statistics such as RMS error and bias. Daily and monthly time series show the trends in performance and are derived from innovation vectors. Development of the automated verification system continues and will also allow for a human element – the METOC expert will eventually be able to perform quality control as products are generated.

2.1.5 Graphical Products

Two-dimensional products are rendered using Generic Mapping Tools (GMT) from the University of Hawaii, and transparent PNG overlay images are created for display within the applet. Up to two products may be displayed in each tab. Products are created as transparent overlays, as are geographical reference information, such as coastlines, political boundaries, and latitude and longitude lines. These overlays are layered over a base map, usually a shaded topographical map. Certain data products may also be overlaid on products; currently, the applet displays METAR observations in a conventional station model.

Strike warfare, carrier air operations, and electromagnetic propagation have been established as significant priorities for NOWCAST. Carrier operations and strike warfare depend upon ceiling and visibility conditions and the accurate and continual assessment of these environmental variables. Thus, physical weather elements such as ceiling and visibility were among the initial products produced by NOWCAST; derived products with value to aviation interests, such as flight category, have also been incorporated. These are presented as color-shaded regions highlighting areas of interest (e.g. low visibility, low ceilings), and the remainder of the plot is left transparent to allow the user to see through to the background for geographical

reference. Figure 4 shows a cloud ceiling product along with a station interrogation pop-up window. Right-clicking on a plotted station allows the user to view extended details that may not be visible on the image.

Satellite cloud imagery is rendered in greyscale with translucency. White pixels are rendered as fully opaque, and darker grey pixels are more transparent, allowing for the background topography to be seen through the cloud; the infrared temperature features, although subtle, can still be seen without obscuring the base map.

NEXRAD products such as base reflectivity, echo tops, and hourly precipitation rates are available both as mosaic products and for single radar locations. Radar reflectivity products follow an accepted color scale convention, with transparency in precipitation-echo-free regions, as shown in Figure 5. The single-station products incorporate navigation among nearby radar locations in addition to individual radar product choices. Figure 6 shows the active radar (red icon), other available radar locations (green icons), and radial velocity on an inbound/outbound scale.

Lightning can be displayed as a data type over other products. Bolts are displayed, seen in Figure 5, in different colors for in-cloud and cloud-to-ground strikes. Bolts are displayed immediately as the lightning data are available, and are displayed for 15 min following the strike.

Wind profile plotting has recently been added to the Nowcast applet. Fig. 7 shows the applet with NEXRAD velocity-azimuth display (VAD) profiles in the right panel. Quality-control information that accompanies the NEXRAD data is used as a filter to display only the values below a critical error threshold. Barbs follow plotting conventions with respect to direction and speed, and are colored according to magnitude. The profiles may be animated and remain displayed when viewing other tabs.

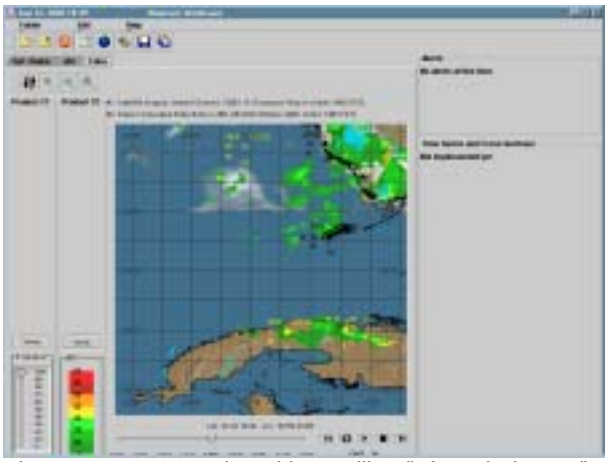

Fig. 5. Nowcast applet with satellite (infrared channel), mosaic radar reflectivity, lightning, and METAR data.

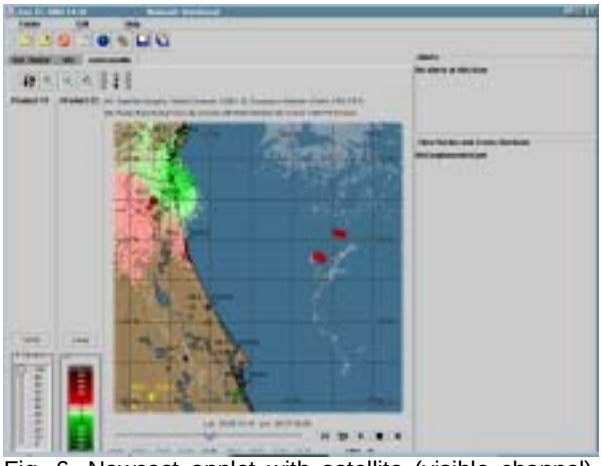

Fig. 6. Nowcast applet with satellite (visible channel), single-station NEXRAD radial velocity, radar locations, and METAR data.

Fig. 4. Screen shot of Nowcast applet with ceiling product and METAR interrogation display.

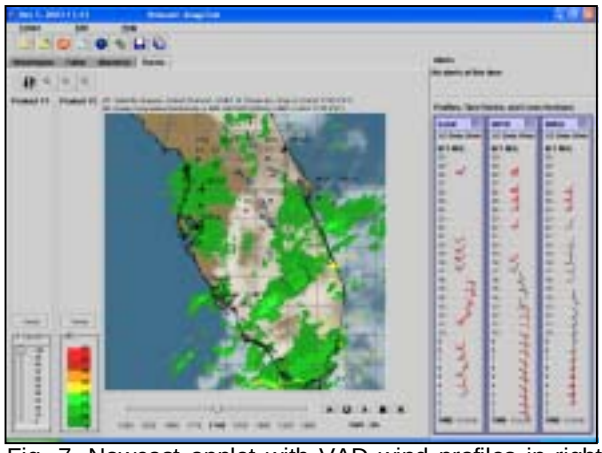

Fig. 7. Nowcast applet with VAD wind profiles in right frame.

2.1.6 Tier 4

Raw data enter the NOWCAST system at Tier 4, the database repository for all available environmental data. Fused NOWCAST fields are written back to Tier 4 and are subsequently made available for use in external applications, including chemical/biological agent dispersion models and electromagnetic/electrooptical (EM/EO) propagation path predictions.

3. FUTURE PLANS FOR NOWCAST

Previous work in NOWCAST has concentrated on the acquisition and display of data from a variety of data sources. Future work will focus on providing innovative nowcast products and incorporating data sources unique to the battlespace.

Continued progress will be made with 3.5DVAR to integrate Doppler wind fields, implement the NCAR Thunderstorm Autonowcaster. Existing architecture will be leveraged and expanded to include tactical on-scene radar data from outside the NEXRAD network. A prototype NOWCAST system will be fielded outside the laboratory, where access to on-scene sensors will supplement less restricted data sources.

Planned products include additional wind profiler plots, tactical radar imagery, icing and turbulence risk, wind shear and microburst risk, electromagnetic duct height, modified refractivity profiles, illumination analyses, and the inclusion of battlespace weather sensor data. Products that require a meteorological background for interpretation will be designed specifically for the METOC community; derived products of value in operations and decision-making will be provided to the warfighter community.

For more information on NOWCAST for the Next Generation Navy, please refer to the project web site:
http://www.nrlmry.navy.mil/Apps/nowcast

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4. REFERENCES

Cook, J., and J. McCarthy, T. Tsui, 2000: Nowcast for the Next Generation Navy. Preprints, Battlespace Atmospheric and Cloud Impacts on Military Operations (BACIMO) Conference, Fort Collins, CO.

Geiszler, D., and J. Cook, P. Tag, W. Thompson, R. Bankert, and J. Schmidt, 2000: Evaluation of Ceiling and Visibility Prediction: Preliminary Results over California Using the Navy's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). Preprints, Ninth Conference on Aviation, Rnge, and Aerospace Meteorology, Orlando, FL. Amer. Meteor. Soc., 334-337.

Geiszler, D., and J. Strahl, J. Kent, J. Cook, G. Love, J. McCarthy, L. Phegley, J. Schmidt, S. Bargsten, F. Franco, L. Frost, M. Frost, D. Grant, R. Mantri, D. Martinez, and L. N. McDermid, 2003: FBE-J Part II: A Real-Time Application of an On-Scene Numerical Weather Prediction System (COAMPS-OS™). Preprints, 19th Conference on Integrated Information Processing Systems, Long Beach, CA. Amer. Meteor. Soc.

Geiszler, D., R. Wade, and J. Cook: The Naval Research Laboratory's Satellite Server (NRLSAT): An Automated Cloud Verification System for COAMPS-OSTM.). Preprints, Battlespace Atmospheric and Cloud Impacts on Military Operations (BACIMO) Conference, Monterey, CA.

Naval Research Laboratory, Marine Meteorology Division, 2002: Nowcast for the Next Generation Navy. [Available from the Naval Research Laboratory, 7 Grace Hopper Ave., Monterey, CA, 93943-5502]

Strahl, J., and D. Geiszler, J. Kent, J. Cook, G. Love, J. McCarthy, L. Phegley, J. Schmidt, S. Bargsten, F. Franco, L. Frost, M. Frost, D. Grant, R. Mantri, D. Martinez, and L. N. McDermid, 2003: FBE-J Part I: A Real-Time Application of Naval Nowcast and Forecast Technology. Preprints, 19th Conference on Integrated Information Processing Systems, Long Beach, CA. Amer. Meteor. Soc.

Zhao, Q., and J. Cook, K. Sashegyi, Q. Xu, L. Wei, 2001: A real-time, three-dimensional cloud analysis system at the Naval Research Laboratory. Preprints, 14th Conference on Numerical Weather Prediction, Fort Lauderdale, FL. Amer. Meteor. Soc., J116-J117.