Nowcast for the Next Generation Navy

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Introduction

Nowcast for the Next Generation Navy (NOWCAST) is a system being developed by the Naval Research Laboratory (NRL), under sponsorship by the Office of Naval Research (ONR). NOWCAST is an enterprise-class, network-centric, data fusion system that will allow the forward-deployed battlegroup to automatically and continuously fuse meteorological data from available sources to characterize their battlespace environment. NOWCAST will continuously transmit the updated products directly to end users and will allow them to tailor the products to their specific warfighting and decision making requirements, thus providing a capability for common environmental situational awareness. Another goal of NOWCAST is to automate meteorological data quality control and to provide the decision maker with a measure of product confidence based on a real-time verification system. This paper describes the background and functionality of NOWCAST.

Objective

The complexity of the battlespace necessitates the automated fusion of environmental information to maintain common situational awareness. The battlegroup of today has limited capability to sample the environment, has no capability to efficiently fuse the sparse information that is available, nor does it have the ability to share a common, consistent picture of the battlespace environment among its components. However, new forward deployed sensing systems, advances in data fusion technology, and the omnipresence of the internet presents an opportunity to overcome this limitation. Automated shipboard sensing systems, unmanned aerial vehicles (UAVs), forward deployed ground stations, shipboard weather radar, tactical dropsondes, and high refresh rate geostationary satellite data systems are in various stages of development and fielding. None of these sensors or systems alone presents the full environmental picture; however, work directed towards aviation support at the National Center for Atmospheric Research (NCAR) and at the Massachusetts Institute of Technology, Lincoln Laboratory (MIT LL) have demonstrated how artificial intelligence techniques may be used to fuse these types of sensor data into a coherent, consistent view of the constantly evolving local environment. Other techniques developed at NCAR and MIT LL are used to identify significant meteorological features and to track them using automated techniques. These tracking techniques allow the features to be extrapolated into the near-term future (1 to 2 h) for short-range forecasts or “nowcasts.”

NRL has developed a forward deployed mesoscale data assimilation system called the Tactical Atmospheric Modeling System (TAMS-RT). TAMS-RT is currently being deployed at all Navy operational meteorology and oceanography (METOC) centers. The core of TAMS-RT is the atmospheric component of the NRL Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) (Hodur, 1997). In addition to 48 h mesoscale forecasts produced twice daily, TAMS-RT can execute a multi-variate optimum interpolation (MVOI) analysis process on an hourly basis. (MVOI will soon be replaced by a 3-D variational technique.) The analysis uses the local mesoscale forecast fields as background or "first-guess" conditions and blends in observational data. Within NOWCAST, the resulting analysis and forecast fields can then be combined with the data extrapolation methods described above using artificial intelligence (AI) techniques to extend the range from 2 to 6 h. The AI techniques being developed rely on real-time verification data to dynamically adjust weights in a fuzzy logic-based blending algorithm. This fused database of environmental conditions can be updated continuously (possibly every 5-15 min.) and specific products may be automatically derived from it. Products, individual data streams, and verification data may then be served to end users using web-based client/server technology. From the end user's perspective, the system will allow them to use a "shopping cart" analogy to select and subscribe to the specific products suitable for their use. Such a system, built on the DII/COE compliant base architecture, will give the battlegroup a new capability to effectively provide integrated, accurate, real-time, consistent, useful environmental information tailored to the individual needs of the warfighter.

Accomplishments

Although the development of a prototype Nowcast system has just begun, several key components of the enabling technology are in place:

- TAMS-RT has been deployed at the Navy regional centers and a shipboard transition is in progress.
- TAMS-RT is able to use conventional data and satellite cloud drift and water vapor tracked winds in an hourly analysis cycle.
- The collection of shipboard weather radar data has been demonstrated.
- A project to develop a ceiling and visibility NOWCAST product has been initiated with support from the Navy, NASA, and FAA.
- The WeatherWeb project, sponsored by the Deputy Under Secretary for Defense (S&T) Smart SensorWeb program, has been initiated and will demonstrate how to provide NOWCAST with weather data over traditionally data-denied target areas.
- The NOWCAST high-level architectural design and baseline communication requirements have been documented.

Figure 1 is a schematic diagram of the NOWCAST system and data flow showing the interaction with the database and TAMS-RT components. The client/server design, including the planned extension to the Common Operational Picture (COP), and the shipboard radar interface are also shown in the figure. NOWCAST servers will reside on the battlegroup network along with TAMS-RT. TAMS-RT will produce the local short-term mesoscale forecasts and hourly analyses that will be used as background conditions for NOWCAST. These fields will reside in the database servers and will be retrieved by NOWCAST once every hour. The database is also the repository for almost all other environmental data available to the battlegroup. NOWCAST will retrieve observational data every 5-15 minutes and the data will be used in an automatic verification system to compare with the verifying NOWCAST products. A separate flat file database of shipboard radar observations will also be retrieved periodically. These data will have been preprocessed locally aboard the radar-equipped ships and transmitted to the NOWCAST server. The preprocessing should also provide local wind shear and microburst processing once every minute. If significant wind shear is detected, an alert and the location will be transmitted to the NOWCAST server for immediate dissemination. The NOWCAST server must also provide user login and authentication services.

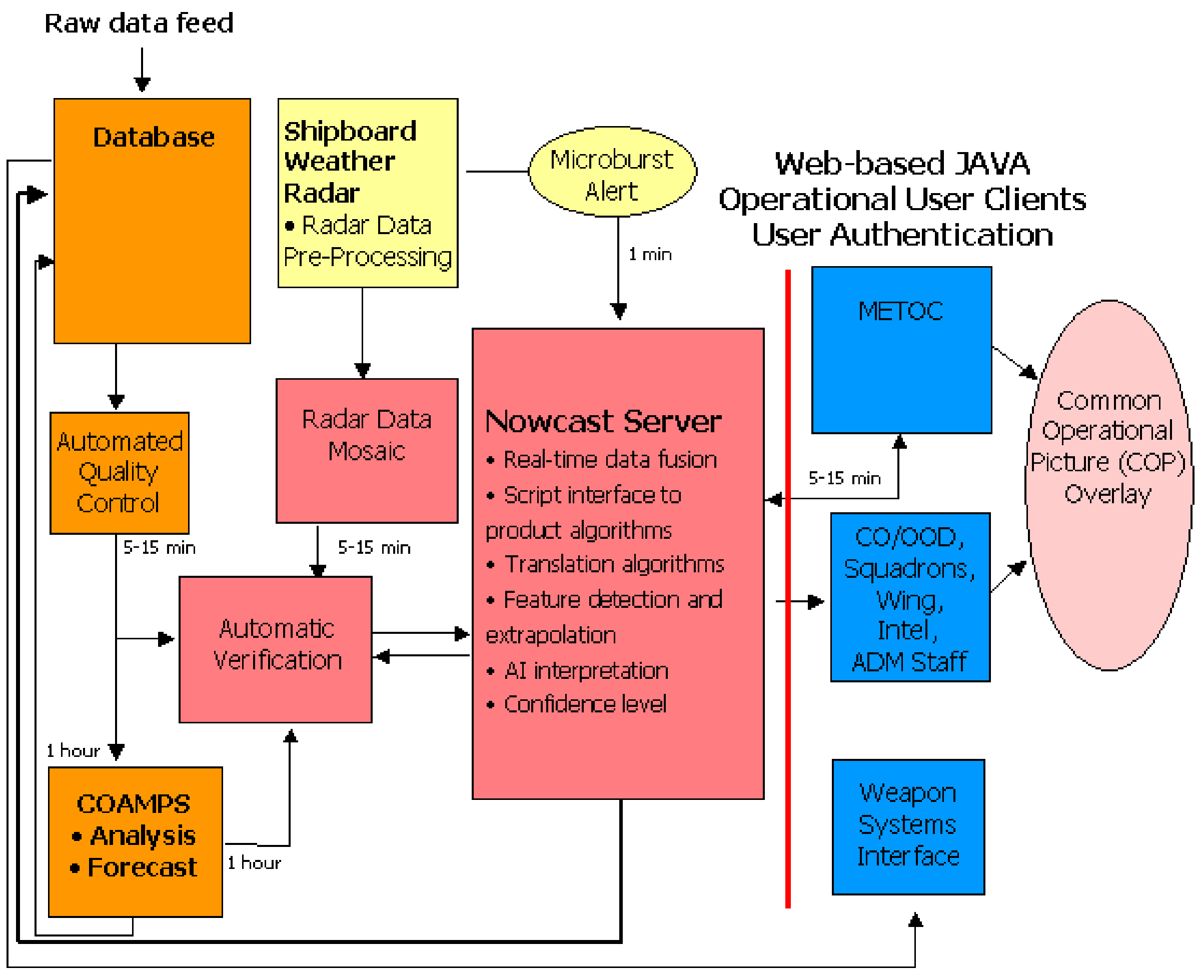

Figure 1. A schematic diagram of NOWCAST. Nowcast server components are shown in red, Nowcast client components in blue, TAMS-RT components in orange, shipboard weather radar processing in yellow, and tactical display connectivity in pink. The heavy red line represents user authentication.

Figure 2 represents a refined picture of the architecture including the technology choices that have been made for the prototype system. NOWCAST is a four-tier internet application. Tier 1 represents the client web browser – Java applet user interface, which can be activated from any properly configured web browser on the network. Tier 2 is the secure HTTP server the applet interacts with and the Java servlets used to maintain session connectivity to automatically refresh dynamic content. Tier 2 also contains the Internet Relay Chat (IRC) server and a Lightweight Directory Access Protocol (LDAP) database. The IRC capability is designed so the end user may interact over the network with the local METOC experts who are the NOWCAST service providers. LDAP is used to maintain run-time information and end user configuration information. Tier 3 represents the real-time NOWCAST product engine where data is fused and end user products are continuously derived from the updated information. Tier 4 represents the production of raw data from sensors (including radar) and background analysis and forecast results produced by TAMS-RT.

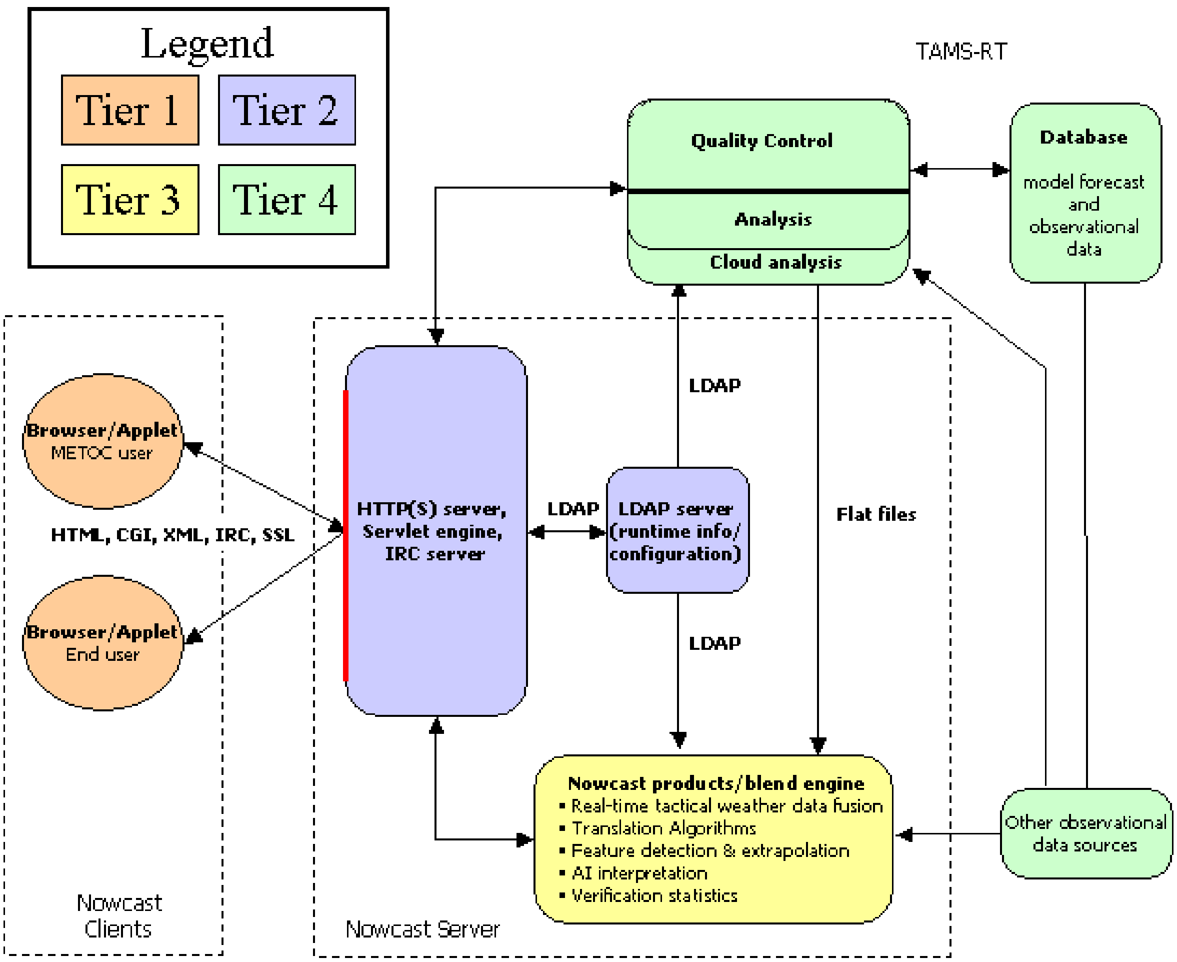

Figure 2. Nowcast architecture showing four-tier design.

The NOWCAST Java client design is based on the concept of data layers (or overlays), where each layer is geographically registered to a user-defined map background. The data layers are shown in Figure 3. The map may be panned and zoomed for viewing a more specific region of interest and a time slide will be provided to control the time looping. The user may select data layers for viewing and may bring up a properties screen where the graphics can be customized. A click on a position will bring up a window showing the closest observation (in space and time) and a double click will bring up a time series for that location covering the past 24 h.

In addition to the data layers, fused data products may also be toggled on and off the display. Multiple data products that provide information related to a common task or warfare area may be grouped together into a warfare folder. These folders may be saved on the server and recalled for editing. All open data, products, and folders will dynamically refresh with the latest available data at the 5-15 minute update rate.

The Nowcast server will provide administration support tools to manage user accounts and profiles through a custom version of the Java client specific to the local METOC service provider. The METOC client will automatically display all the data types (overlays) by default and has special privileges to let the METOC expert perform quality control (QC) and tag "bad" data and model output. Tagged data will not be used by NOWCAST nor displayed to end users until the METOC expert toggles the QC flag back to "good."

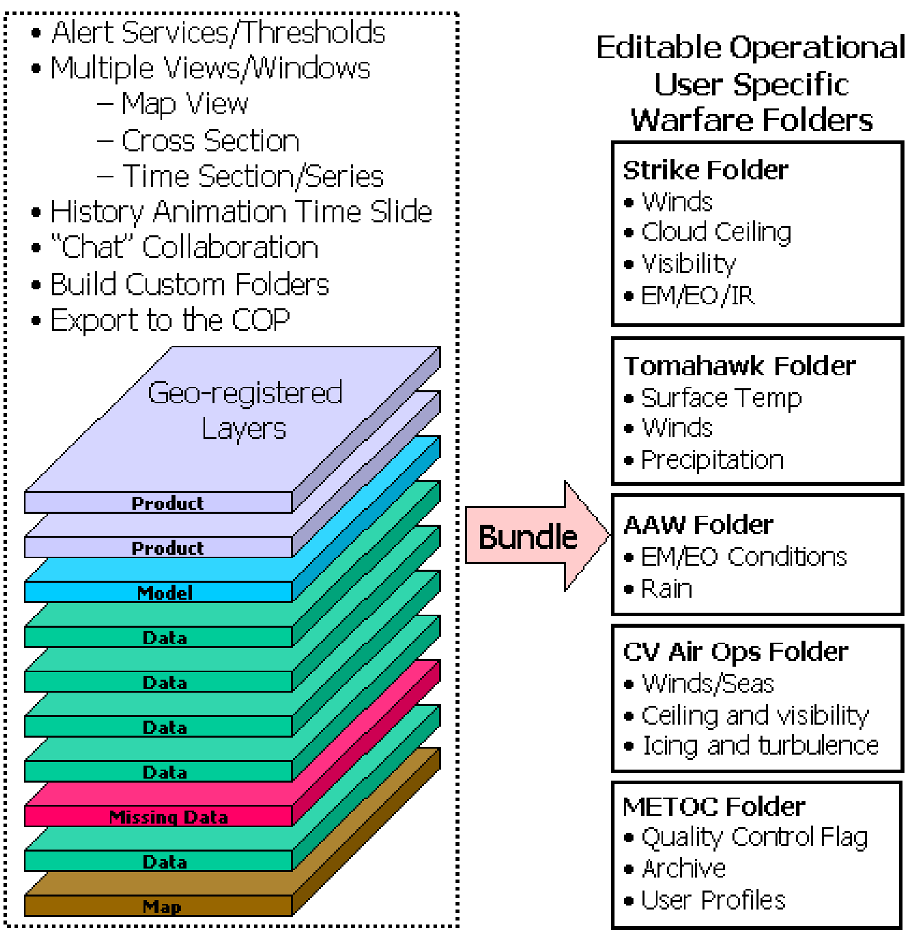

Figure 3. Nowcast client concept showing layered design.

Both METOC and end users will be able to set visual and audio alerts for their data. An IRC "hot" button on the client will allow the user to spawn an IRC session directly with the responsible METOC office and it is anticipated that these sessions will be used to interact with the on-scene METOC experts about critical data and product interpretation. Since everyone in the NOWCAST system “sees” the same picture of the environment, the METOC experts and the end users can discuss and relate to a common visualization of the data and products. A future enhancement to NOWCAST will be to make the graphics windows a shared whiteboard allowing truly collaborative data and product.

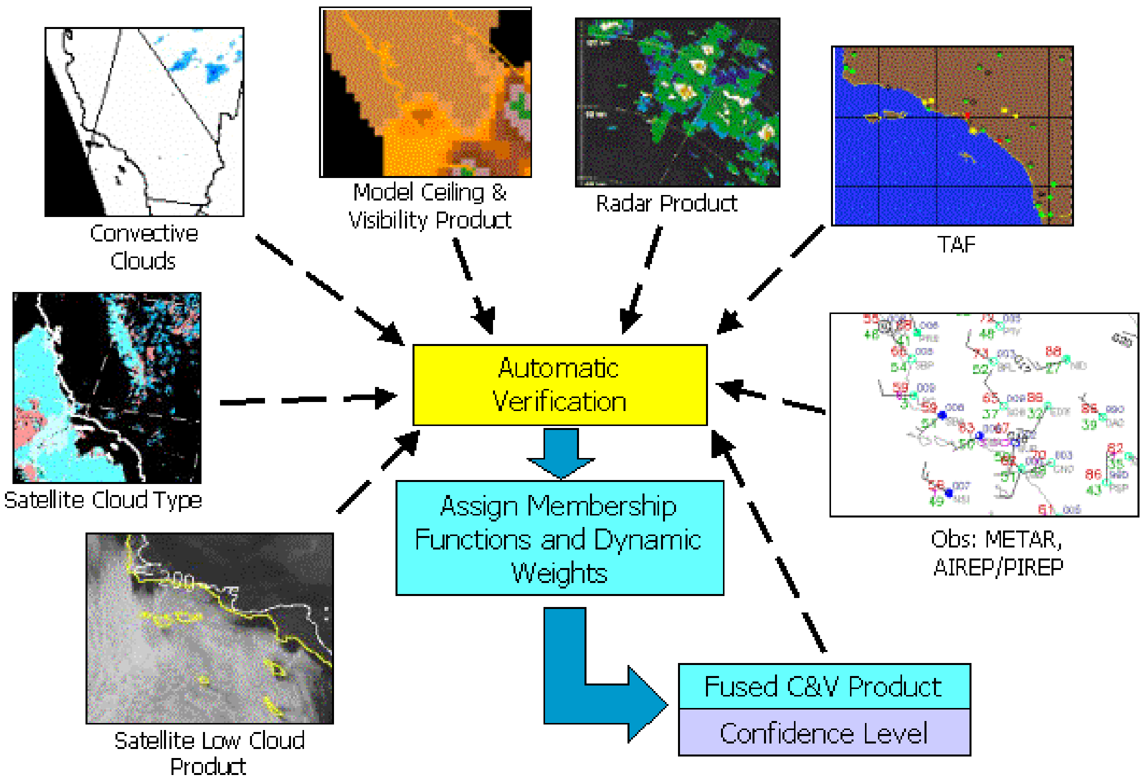

Figure 4. NOWCAST process for ceiling and visibility product.

Early in the system conceptualization, two high priority areas for initial support were identified: carrier air operations, including strike warfare (STW), and electromagnetic (EM) propagation assessment. Both carrier air operations and STW rely heavily on ceiling and visibility (C&V) assessments; in fact, operational forecasters spend 40% of their time developing such guidance. Therefore, a C&V product was identified as the first desirable fused-technology product. Initial steps of developing model-derived background C&V fields are described in Geiszler et al. (2000). Figure 4 shows schematically how the NOWCAST production process for a C&V product is being implemented. All available data and background fields are used in an automatic verification system to compare the C&V observations with the prior NOWCAST “prediction” to compute an objective measure of confidence (score) for each data type. The scores are then used to develop membership functions and dynamic weights for the fuzzy logic AI algorithm. This algorithm fuses the data and background fields and extrapolates the results for the next few hours.

Interactions with NCAR and MIT LL have identified other mature technologies that would make valuable additions to the NOWCAST product suite. A list of products planned for development is given in Table 1. An Integrated Product Team (IPT) is planned for operators and end users to provide additional feedback on the products, displays, and system management functionality.

Table 1. Planned data and fused products for Nowcast.

- Air Temperature
- Relative Humidity
- Wind Speed and Direction
- Precipitation Type and Rate
- Sea Level Pressure
- Altimeter Setting
- Satellite Imagery
- Radar Reflectivity
- Cloud Ceiling Height
- Cloud Top Height
- Cloud Fraction and Type
- Visibility
- Thunderstorm AutoNowcaster
- Aircraft Icing
- Clear Air Turbulence
- Wind Shear and Microburst Alert
- Electromagnetic Duct Height and Modified Refractivity Profiles
- Optimal Trajectory
- Heat Index
- Illumination
- Sunrise/Sunset Times
- Terrain Height and Land Use Background Maps

At sea communications requirements for NOWCAST have been estimated. These estimates assume that the area of coverage represents 1/32nd of the globe (45 X 45 deg box). The size of the battlegroup is estimated to be 14 ships, one equipped with weather radar and one (the aircraft carrier) designated as the NOWCAST service provider where the data fusion engine and TAMS-RT systems will reside. For a shore-to-ship link to transmit conventional observations, weather web data, satellite data, and lateral boundary condition fields to the carrier to support TAMS-RT, the estimated peak data rate is 10.6 kbits/sec twice a day for an hour each time (the bulk of the transmission is related to the 00Z and 12Z synoptic times). For ship-to-ship links to continuously transmit shipboard observation data, radar data, and NOWCAST web-based products, the estimated aggregate rate is 242.8 kbits/sec, which can be provided by a T1 circuit to the carrier. Since this estimate includes supporting NOWCAST product dissemination to ten smaller ships, the individual ship's bandwidth estimate to transmit their observation data and to receive products 21.5 kbits/sec. For the ships equipped with radar, the estimate is 49.7 kbits/sec due to the addition of the radar data stream.

Although the process of developing a prototype NOWCAST system and C&V product has begun, there are several areas of active R&D:

- Development of the AI data fusion engine; C&V is the first product to go into the fusion engine.
- Integration of shipboard observations, weather radar, and satellite data into the engine.
- Determination of optimal data density and sampling frequency.
- Development of the automated verification capability.
- Development of the web-based client/server application.
- Development of tailored end-user products.

Conclusion

NOWCAST will be an automated, portable, environmental data fusion and web-based data dissemination and display system for the battlegroup and other regional enterprises (e.g., a Navy or Joint METOC facility). As a multi-tiered enterprise-class solution, NOWCAST is designed to provide the best characterization of the battlespace environment to end users to support informed, integrated, decision making. NOWCAST is an observation-oriented, network centric concept in which a local real-time environmental database is frequently updated to generate fused products that are automatically and continuously transmitted back to configurable end user client applications, thus maintaining a common environmental situational awareness. NOWCAST will allow the forward-deployed user to add significant value to the volume of raw, perishable atmospheric data available on-scene by intelligently fusing the information with locally produced mesoscale model background fields. Feature detection and tracking algorithms can make use of high temporal rate data to extrapolate features (e.g., gust fronts and precipitation areas) into the near-term (0 – 2 h). Artificial intelligence (AI) techniques may be used to blend the extrapolated results with fields produced from a mesoscale model to extend the forecasts to 6 h. This is important because the spin-up time of the mesoscale model is on the order of 6 h, thus NOWCAST fills the gap at the beginning of each data assimilation cycle.

Acknowledgements

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