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Toward dynamic adaptivity: steering the WRF model on the Unidata LEAD test bed

Thomas Baltzer, Steven Chiswell, Ben Domenico and Mohan Ramamurthy
Unidata Program Center, UCAR, Boulder, CO

1. INTRODUCTION

In response to a pressing need for a comprehensive national cyberinfrastructure in mesoscale meteorology, particularly one that can interoperate with those being developed in other relevant disciplines, the National Science Foundation in 2003 funded a Large Information Technology Research (ITR) grant known as Linked Environments for Atmospheric Discovery (LEAD). This multi-disciplinary effort involving nine institutions and some 80 scientists and students is addressing the fundamental IT and meteorology research challenges needed to create an integrated, scalable framework for identifying, accessing, decoding, assimilating, predicting, managing, analyzing, mining, and visualizing a broad array of meteorological data and model output, independent of format and physical location (Droegemeier et al, 2005).

An important aspect of the LEAD project is dynamic adaptivity. This concept includes being responsive to weather conditions in performing modeling. An algorithm for choosing a location of interest based on predicted precipitation from the NCEP North American Model (NAM, formerly known as Eta) forecast has been devised at Unidata/UCAR. The center latitude and longitude of this location is being utilized to steer both the Workstation Eta and Weather Research and Forecast (WRF) models, the latter runs on the Unidata LEAD test bed, with each prediction cycle (four times daily). The results are being stored on the test bed, cataloged using Thematic Realtime Environmental Distributed Data Services (THREDDS) Cataloging and distributed via the Open-source Project for a Network Data Access Protocol (OPeNDAP – formerly DODS). We've also generated Unidata Integrated Data Viewer (IDV) bundles being developed that allow one to view the most recent regional runs as compared with one another and with the most recently received NAM data. Note that leveraging the THREDDS 'latest' capabilities, a single bundle can be used to visualize the most recent data in the same way each time. This work is intended to enable the LEAD team to work toward developing these and far more sophisticated capabilities within the GRID computing environment in which it is ultimately to be deployed.

2. DESCRIPTION OF THE EFFORT

In a conversation inspired by Kelvin Droegemeier's 2004 AMS LEAD presentation, a number of us at Unidata discussed whether there was a way to connect a set of existing tools so that a high resolution local model could be guided by some metric of where the "interesting" weather would occur during the forecast time. Over the ensuing months the four times daily operational environment shown in the following figure was devised and implemented at the UCAR Unidata Program Center.

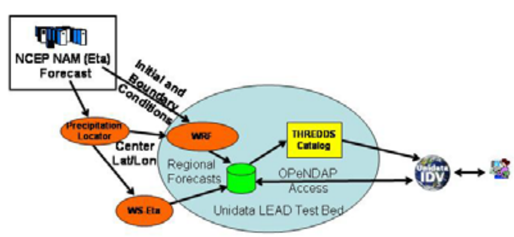

Figure 1: Configuration of the NWP work at Unidata/UCAR

As shown in figure 1, NAM Model forecasts are fed to the GEMPAK based Precipitation Locator algorithm. The Locator determines a center latitude and longitude of the most significant predicted precipitation at the

Corresponding author address: Thomas S.V. Baltzer PO Box 3000 Boulder Colorado, 80307: tbaltzer@ucar.edu

CONUS scale. This is fed to both the WRF and Workstation Eta models which are configured to use the location as the center of their regional domain. The resulting regional forecasts are stored on the Unidata LEAD Test Bed system, and made accessible from remote locations via an OPeNDAP Server and cataloged using the THREDDS cataloging system. The end user is then able to view the catalog information and interact with the data holdings using the Integrated Data Viewer (IDV) for which specific bundles have been devised.

Research Objectives

The primary research objectives of this work are to 1) Demonstrate Dynamic Adaptive steering of regional models, 2) Provide results on a LEAD test bed system to the LEAD enterprise and Unidata community via tools to be used by the LEAD project and 3) Integrate some of the LEAD technologies in an early prototype fashion to enable better integration of these elements for the final LEAD system.

Locator Algorithm

The mesoscale model domain is determined using an objective weighting method to select the region of interest. This method is currently using the 24 hour accumulated precipitation forecast from the 12km NAM which is distributed operationally via NOAAPORT as the predictor for the region of interest (ROI) function. This function can be augmented to include other predictors of interest in the future.

The center of the model domain is computed using GEMPAK's Gaussian Weighted Filter using normal distribution of weights (GWFS) for the 24 hour precipitation field (P24M) accumulated from F006 to F030. The weighted field is interpolated to CONUS station locations using GEMPAK's GDGSFC program. The model central latitude and longitude is obtained from the station location with the maximum weighted ROI value.

See the companion paper by Chiswell et al. in this session for more information about the locator algorithm.

Mesoscale Model Configurations

The Weather and Research Forecast (WRF) model run uses the NCEP 40 km NAM CONUS data for initial and boundary conditions. It is configured to a 12km grid spacing with a 144x144 grid domain. Model output is generated hourly for 36 hours beginning at the same time as the input NAM.

The Workstation Eta model run uses three hour ETA grids from F000-F030 for the outer domain which uses 0.098 degree grid spacing. The inner nest is run using 0.049 degree grid spacing. Model output for the inner forecast grid is generated hourly for T+6 to T+30 hours from the initial boundary run time.

3. Results

The ability to integrate tools to be used within the LEAD GRID context has been well demonstrated by this effort. The key technologies involved have performed very well for many months in a quasi-operational setting at Unidata. As a result, we have approached our User's Committee with directions for how to take this work forward for use by the Unidata Community Members and how to adapt what has been developed thus far to their needs while we also adapt it to the needs of the LEAD project.

Early Storm Tracking Results

The Image sequence below shows how the locator algorithm successfully tracked a storm system that started in Texas and moved Northeast ultimately resulting in a severe ice storm that shut down three of the Atlanta airport's four runways and snapped power lines robbing 102,000 customers of electricity in Georgia in late January 2005. The grey rectangles show the locations selected for the Workstation Eta regional model runs whose precipitation predictions are shown in color filled contours. The NAM precipitation forecasts are shown in overlaying contours.

Figure 2: Early results chasing an ice storm

Recent Storm Tracking Results

The image sequence in figure 3 shows how the locator algorithm used the predicted paths of Hurricane Katrina as it approached New Orleans. The images show the migration of the predicted path as well as the degree of detail the mesoscale models can provide to end users. In the images, the larger domain WRF model run is shown in contour with the smaller domain WS-Eta shown in color contours.

The images are taken from three consecutive WRF and WS-Eta runs. The same time step of 2005-08-29 12:00:00 Z is plotted to show how the prediction changed from one forecast to the next.

Future Directions

At present we are working with LEAD colleagues at Millersville and Howard Universities to leverage these ideas into a steered ensemble forecast system that brings in another LEAD tool the Algorithm Development and Mining System (ADaM) developed by our LEAD colleagues at the University of Alabama in Huntsville. See companion paper by Clark et al. in this session.

We have also begun work with LEAD colleagues at the Center for the Advanced Prediction of Storms (CAPS) at Oklahoma University to assimilate initial conditions for the WRF model using the ARPS Data Assimilation System (ADAS), another tool in the LEAD vision.

Ultimately, many of these tools will be integrated together using a Service Oriented Architecture (SOA) configuration leveraged by a workflow composition capability being created by our LEAD colleagues at Indiana University.

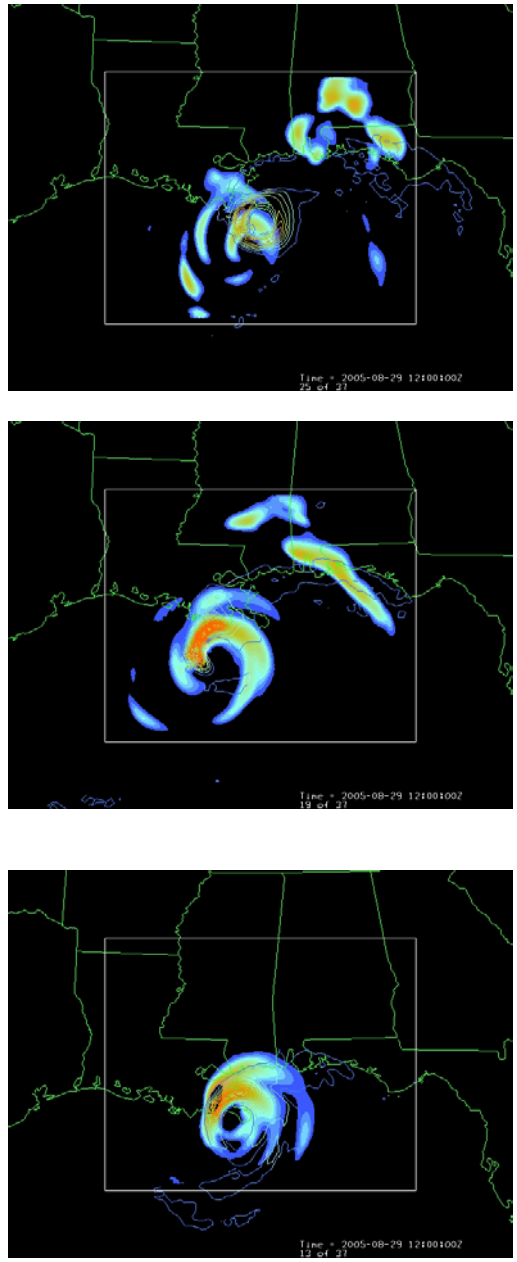

Figure 3: More recent results chasing Katrina

4. ACKNOWLEDGEMENTS

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5. REFERENCES

Chiswell, Steven, and B. Domenico and J. Weber: Real-time steering of mesoscale forecast models using objective techniques. 22nd International Conference on Interactive Information Processing Systems (IIPS), 86th Americal Meteorological Society Annual Meeting, Atlanta, Georgia.

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THREDDS Catalog Specification http://www.unidata.ucar.edu/projects/THREDDS/tech/catalog/InvCatalogSpec.html

OPeNDAP Project http://www.opendap.org/

The Integrated Data Viewer (IDV) http://www.unidata.ucar.edu/software/idv/

The Weather Research & Forecasting (WRF) Model http://www.wrf-model.org/index.php