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DEVELOPING THE ADAS/ARPS AS A SATELLITE DATA ASSIMILATION TESTBED AT THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

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1 INTRODUCTION & PURPOSE

With the co-location of NASA Marshall Space Flight Center, its Short-term Prediction Research and Transition (SPoRT) Center, the Atmospheric Science Department, and the Huntsville National Weather Service Forecast Office (HUN WFO), at the University of Alabama in Huntsville (UAH), the components are in place to support mesoscale, short-term prediction (0-24 h period) research, which focuses on the use of satellite data and its assimilation into numerical weather prediction (NWP) models.[‡]

This presentation describes the "UAH-NASA SPoRT Remote sensing, Nowcasting and Data assimilation Testbed" (*RND Testbed*). This Testbed is comprised of two main components: 1) 0-6 h nowcasting activities (that meshes remote sensing, observations, and NWP), and 2) NWP and data assimilation in support of 6-24 h forecasting (that relies on satellite data assimilation). For the second component, the Advanced Regional Prediction System (ARPS) Data Analysis System (ADAS; Case et al. 2002; Xue et al. 2003) modeling system is being developed as the NWP infrastructure within of the Testbed, to support various activities. This presentation will overview the specific datasets assimilated by ADAS to date, as well as the research being performed.

The Testbed is viewed as a decade-long effort that will evolve to meet the interests for testbed-oriented research, in support of a range of research and forecast activities across the NWS Southern Region. It will therefore serve as a framework for organizing basic and applied short-term prediction and data assimilation activities across the southeastern U.S.

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2 TESTBED COMPONENTS

Because of the suite of unique instruments already operating in the Huntsville, Alabama vicinity, this Testbed will be designed for *perpetual-mode operations*, collecting data continuously in support of various UAH science projects. The Testbed may occasionally be enhanced with aircraft and experimental instrumentation from other scientists (both domestic and international) within intensive observation periods (IOPs) as specific research objectives are addressed.

The Huntsville area is very well-suited to provide perpetual Testbed-related field experiment support for short-term prediction and mesoscale research. This is due to the availability of the following instruments within the UAH "STORMnet" [see Fig. 1(a-b); labeled "2a" and "2b"]:

- C-band dual-polarization Doppler radar ("ARMOR"; located at the Huntsville International Airport, 14 km southwest of NSSTC; new in late-2004);
- The Mobile Integrated Profiling System (MIPS; PI Dr. Kevin Knupp): 915 MHz wind profiler, a Radio Acoustic Sounding System (RASS), 2 kHz Doppler sodar, 0.905 mm ceilometer, and 12-channel microwave profiling radiometer (MPR); a 0-3 km-profiling Atmospheric Emitted Radiance Interferomenter (AERI) a proposed new instrument;
- Surface weather instrumentation and real-time satellite data (GOES & MODIS);
- NWS WSR-88D radar at Hytop, AL (~75 km northeast of Huntsville), near Columbus, MS, and Birmingham, AL.

– The North Alabama Lightning Mapping Array (LMA), and the National Lightning Detection Network (NLDN);
– Other instruments, radar and remote-sensing data available via the Redstone Arsenal (RSA; see Fig. 1).

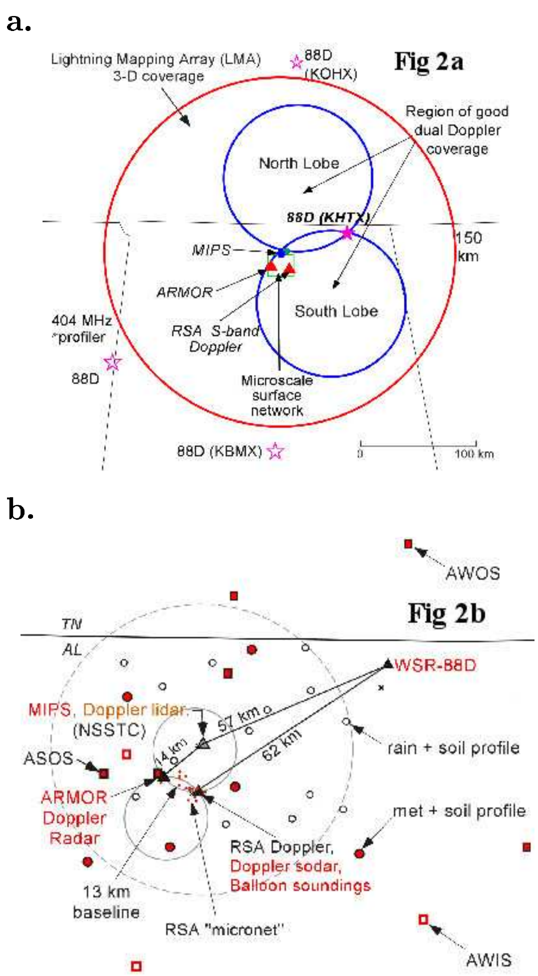

Figure 1: a) North Alabama "STORMnet" showing dual-Doppler and LMA coverage as a result of Hightop, AL and ARMOR radars. Shown also is the S-band Doppler at the Redstone Arsenal ("RSA") on Huntsville's south side, and the WSR-88D Dopplers near Nashville, TN, south of Tupelo, MS, and near Birmingham, AL. b) STORMnet focussed on Huntsville, showing local mesonetwork, rain gage stations. RSA sounding site, and the MIPS system at the NSSTC.

This instrumentation will be bolstered by the (satellite) data assimilation and analysis capabilities of the ADAS, regional mesoscale modeling abilities of ARPS [and eventually the Weather Research and Forecast (WRF) model]. Cloud-resolving modeling from the University of Wisconsin–Nonhydrostatic Modeling System (UW-NMS) and/or the Regional Atmospheric Modeling System (RAMS) are available to support Testbed activities to assess how (microscale resolution) observations link to mesoscale/regional scale flows, as a means of testing hypotheses related to convective scale and mesoscale dynamics, and for error analysis.

The Testbed will provide exciting and unique opportunities for Graduate student research (at UAH and other universities) as they exploit the above observational and modeling infrastructure. Masters and Ph.D. students, as well as Post-Doctoral scientists, can fluently design and conduct specific field experiments within the Testbed for articulating research hypotheses related to short-term prediction.

In particular, the ARMOR is a scanning dual-polarimetric Doppler radar operating at C-band (5625 MHz) with a beam width of 1°. It was originally deployed in Huntsville by the National Weather Service as a local warning radar in 1977 (WSR-74C), refurbished and upgraded to Doppler in 1991. The radar was donated to the UAH Atmospheric Science Department in 2002 and upgraded to dual-polarimetry using the SIGMET Antenna Mounted Receiver in Fall 2004. This radar will serve as an excellent tool for precipitation microphysics–total lightning (via the LMA) related research.

Given the capabilities of the ARPS/ADAS (and other modeling systems), satellite data assimilation activities at UAH will address needs for routine, satellite data-driven short-term prediction and research. The ADAS is a high-resolution (∼2 km) data assimilation system that provides atmospheric analyses at up to ∼15 min frequencies (depending on the data sets assimilated). At UAH, ADAS will be operated in two modes: (a) a regional "Flat" (4-level) set-up for the production of mainly surface weather analyses (see Fig. 2), and (b) a "3D" (50+ levels) mode useful for assimilation experiments that develop methods for using satellite moisture and temperature retrievals from various sources (e.g., GOES/AIRS/GPS moisture, MODIS SSTs). Use of ADAS will facilitate learning how to assimilate a variety of remote-sensing data, including more complicated information such as polarmetric radar, MIPS profiles, and total lightning, datasets which already exist in the near-vicinity of UAH.

ADAS will be run operationally to provide the NWS with high-resolution, accurate analyses. Output from the 3D ADAS will also be used to initialize the MM5 or WRF NWP models for further data assimilation research (e.g., how does assimilation of

MODIS SSTs influence simulations of the sea breeze circulation?; see section 4.2).

The Flat-ADAS research will assist in the validation of the NWS Interactive Forecast Preparation System (IFPS). The IFPS possesses a resolution of 2.5 km, for which validation over the variety of landscapes in the Southern Region (mountains to coastal regions) is a significant NWS challenge, one that ADAS is ideally suited to address, especially as the quality of these analyses improves as data are accumulated via assimilation. Key science questions can be addresses via such Flat-ADAS analyses, including the role the sea-surface temperature plays in modulating near-shore forecasts (with respect to sea breeze development, oceanic convection and tropical cyclone intensities).

The UAH 3D-ADAS will be developed to provide a detailed initialization for the ARPS model (or WRF). *The UAH 3D-ADAS will however emphasize satellite data assimilation*, for which other institutions running ADAS do not. The 3D-ADAS will be a framework for satellite assimilation research, and be developed on regional domains as specific data impact studies are conducted. A host of readily-available data will, over time, be evaluated to enhance the 3D-ADAS via basic research initiatives involving UAH (and non-UAH) Graduate students. Several of these data (not including those listed above) are:

a) Moisture retrievals from GOES, Global Positioning System (GPS), and/or the Atmospheric Infrared Sounder (AIRS) measurements;

b) Rainfall products from the Tropical Rainfall Measurement Mission (TRMM)/Global Precipitation Measurement (GPM) constellation;

c) GOES/MODIS satellite-derived convective cloud signatures in the infrared and visible channels, as used in the convective initiation (CI) nowcast algorithm of Mecikalski and Bedka (2005), for "hot start" initialization;

d) Polarmetric data from the ARMOR radar; e.g., precipitation type, clear-air refractivity;

e) Total lightning (from the North Alabama LMA); also used for "hot start" initialization.

The following sections highlight currently how the Testbed is being utilized and grown as demonstrated through a few short-term prediction and satellite data assimilation projects.

3 RESEARCH FOCUS

Important new research is being motivated over the coming years within this RND Testbed infrastructure. This falls into three main categories: (1) specific satellite data assimilation research for GOES-derived soil moisture, GOES-derived atmospheric moisture and MODIS-derived SSTs, and (2) short-term prediction research toward improved CI and lightning forecasting (see Poster 1.5 in the *Conf. on Meteorological Applications of Lightning Data*), and (3) field experiment activities toward improving understanding of the CI process as related to land-surface heterogeneity (see Poster 3.14 in the *19th Conf. on Hydrology*).

4 PRELIMINARY ACTIVITIES

This section presents preliminary research for three components now ongoing within the Testbed: (1) hourly Flat-ADAS 2 km surface temperature analysis, (2) MODIS SSTs assimilation using MM5, and (3) 0-1 h CI nowcasting at 1 km resolution. More details on each will be provided in the accompanying poster.

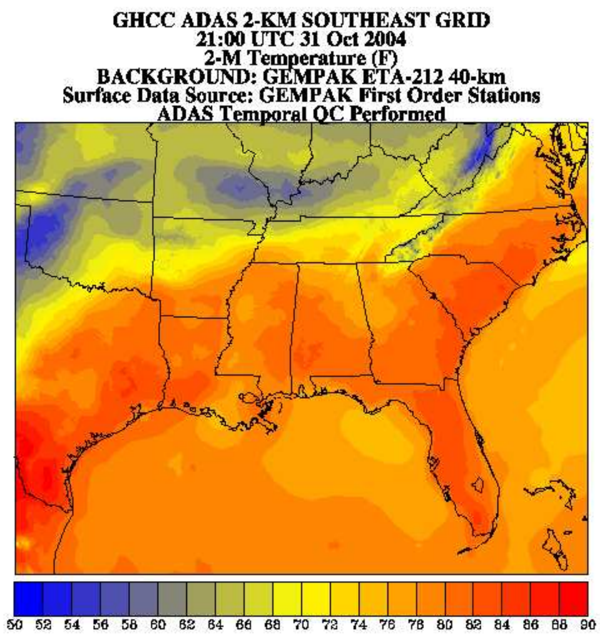

Figure 2: ADAS 2 km resolution surface temperature analysis. This analysis will be enhanced over time as a Testbed product that will include GOES and WSR-88D information to force surface temperatures.

4.1 ADAS Surface Temperatures

Figure 2 demonstrates a 2 km-resolution ADAS surface temperature (°F) field over the southeastern U.S. at 2100 UTC 31 October 2004. This analysis is currently developed from an initial Eta background, and enhanced with METAR. New work over the coming months will enhance this product with MADIS (Meteorological Assimilation Data Ingest System) station information, local mesonetworks, satellite-based skin temperature estimates (converted to air temperatures via empirical relationships), and radar-based cooling estimates (Richard McNider, personal communications). It is expected that this information will assist in the validation of the IFPS forecast system over the NWS Southern Region, and will soon be transmitted via the Advanced Weather Interactive Processing System (AWIPS) to NWS HUN as well as other offices across the NWS Southern Region. Additionally, maps of dew point and wind will be available from this ADAS setup.

4.2 MODIS SST Assimilation and Impact Study

One goal of this project is to use high resolution satellite-derived products to improve NWP forecasting along the coast. Initial work is focused on determining the sensitivity of sea breeze simulations to SSTs. The control run was initialized with the Eta 212 grid (40 km), which includes SSTs from the RTG-SST product (*http://polar.ncep.noaa.gov/sst/*). A six day composite of MODIS EOS SSTs was chosen as the new SST product. To get a quick idea of the impact of this new data, the MODIS SSTs replaced the original SSTs in the initialization fields for a domain including the Caribbean and the Florida Peninsula. Then, 24h forecasts were run at 2 km horizontal resolution. Initial results show that there is sensitivity to the SSTs. These MODIS SSTs will eventually be used in ADAS, with the forecast run using ARPS or WRF.

4.3 CI Prediction

Figures 3(a-b) highlight an example of a 30-45 minute CI nowcast made for a large region of the southeastern U.S. This is based on the methodology of Mecikalski and Bedka (2005), using cloud motion tracking of Bedka and Mecikalski (2005). This research utilizes Lagrangian tracking of growing cumulus in 15-30 minute GOES data to predict new CI. Red pixels in Fig. 3b demonstrate new 1

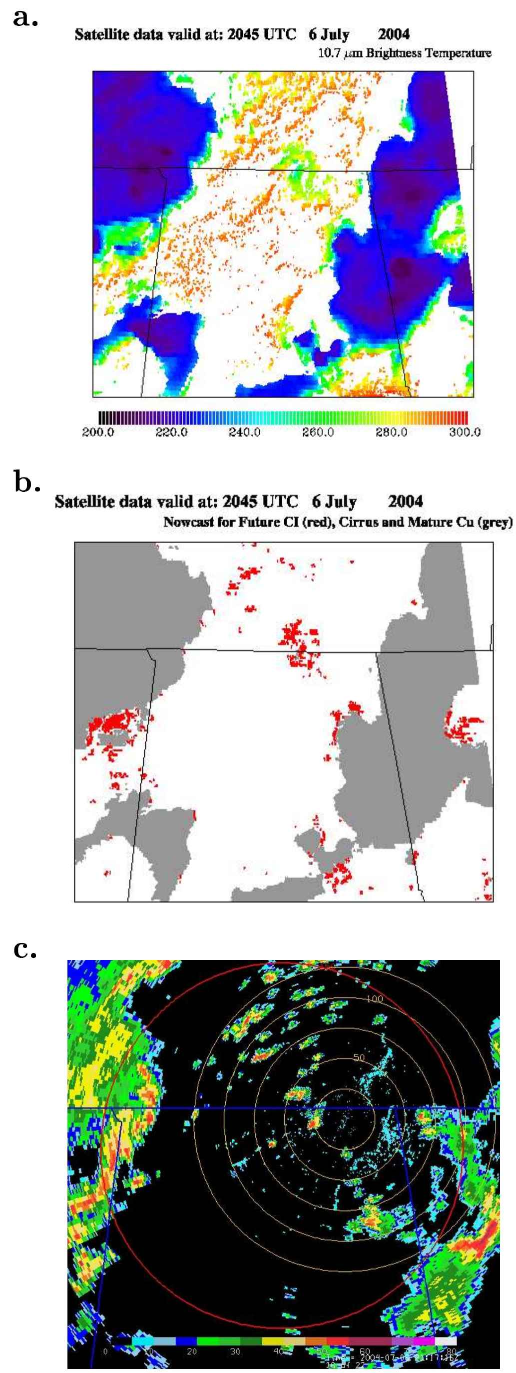

Figure 3: a) GOES 30-min satellite-based forecast of CI at 2000 UTC 4 May 2003 (valid at 2030 UTC); red pixels denote locations where a 25-30 dBZ radar echo is expected to develop. b) WSR-88D radar at the time of CI nowcast, 2030 UTC. Note the correspondence of ≥25 dBZ echoes (green, yellow or red colors) in Fig. 1b with red pixels in Fig. 1a. Grey areas in Fig. 1a are cirrus. This correspondence shows ~60-65% accuracy when pixel-by-pixel comparisons are made (Mecikalski and Bedka 2004).

km pixels that are likely (60-70% likely) to produce a $\geq$35 dBZ echo over the next 30-45 minutes. The radar image (Fig. 3c), when compared to Fig. 3b, demonstrates our current CI prediction capability. New work is assessing the accuracy and relative importance of each GOES infrared field [e.g., 10.7 μm cloud-top temperatures (Fig. 3a), cooling rates, 6.5–10.7 μm channel differences, 13.3–10.7 μm channel differences, as well as ∂(6.5–10.7 μm)/∂t] to CI. We are also refining this methodology to include periodic MODIS infrared imagery, developing the method to predict nocturnal CI, operate well across various convective regimes (e.g., tropical "low-CAPE" versus "high-CAPE" environments), and are progressing toward

a climatology of CI over the southeastern U.S. In addition, Mecikalski et al. (2004) describe developments in 30-75 minute lightning predictions based on GOES infrared trends, exploiting the LMA data stream for this work.

The CI-related aspects of Testbed activities are being expanded into the 2-6 hour prediction environment as a regional land-surface energy model [the Atmospheric Land-EXchange Inverse (ALEXI); Mecikalski et al. 1999] is considered along-side the CI system. In particular, combining ALEXI fields of surface energy fluxes, soil moisture and vegetation characteristics (from AVHRR NDVI data; i.e., fraction cover, moisture stress from ALEXI), NWP model fields (wind, CAPE, moisture convergence), topography, as well as GOES CI "interest fields," will address issues and hypotheses regarding how surface heterogeneity affect CI. (see Poster 3.14 in the *19th Conf. on Hydrology*). A 2-6 h CI probability at 10 km resolution that relies on satellite data is the goal of this component of our project at UAH.

Scientists and students interested in collaborating toward utilizing the RND Testbed for research projects are encouraged to contact the corresponding author at UAH.

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