P2.1 PROGRESS IN APPLYING GOES-DERIVED DATA IN LOCAL DATA ASSIMILATION

Daniel Birkenheuer*
NOAA Forecast Systems Laboratory, Boulder, Colorado

1. INTRODUCTION

The Local Analysis and Prediction System (LAPS) analyzes three-dimensional moisture and other state variables each hour over a multistate domain centered on Colorado. These analyses initialize local-scale, high-resolution models such as the Colorado State University's Regional Atmospheric Modeling System (RAMS) model and NCAR's MM5 (mesoscale model, version 5) on a routine basis. LAPS has been integrated into the Advanced Weather Information Processing System (AWIPS) system as part of the National Weather Service (NWS) modernization. Research to expand LAPS capabilities is one avenue toward providing advanced technologies and new innovations to the operational forecaster.

This paper describes the new satellite capabilities that have been developed for LAPS, using geostationary operational environmental satellite (GOES) derived total precipitable water vapor (GVAP) data for nowcasting and short-range forecasting applications. During the summer of 1999, LAPS was operated for a time both with and without GVAP data to test its impact. Rawinsonde data in the analyzed domain were used for verification.

1.1 *Brief History of LAPS*

Under development since 1990, LAPS combines nationally disseminated data with local data for real-time objective analyses of all data available to the local weather forecast office. LAPS analyses are of suitable quality to initialize a local-scale forecast model. Such models can address specific problems of a small forecast domain with greater detail than can be achieved with nationally disseminated model guidance (Snook et al. 1998).

The LAPS system is routinely tested with new data sources and innovative improvements, using more "conventional" data, which have potential for national dissemination.

During the 1980s FSL conducted forecast exercises to test its workstation prototypes. Forecasters were burdened with the impossible task of reviewing all the incoming data made possible through new technologies, while producing timely forecasts. It became obvious that local data needed to be objectively analyzed in conjunction with nationally disseminated data. Conceived as a resolution to this challenge, LAPS was designed for the purposes of analyzing all local data in real time on an affordable computer workstation and using its own output fields to initialize local-scale forecast models. So far it has been interfaced with RAMS and MM5, but can function with any weather prediction model. A more detailed review of LAPS is available in McGinley et al. (1991).

LAPS integrates all state-of-the-art data as they become routinely available to a field forecast office. Advanced data include Doppler reflectivity and velocity fields, satellite observations including GOES infrared (IR) image data in AWIPS format, wind profiler data, automated aircraft reports, and dual-channel ground-based radiometer data.

2. LAPS MOISTURE ANALYSIS

The specific humidity (SH) module is one of 17 LAPS algorithms that span everything from data preparation and quality control (QC) to actual analysis. In addition to state variables, LAPS also produces highly specific analyses of special interest, such as aircraft icing threat. The major components of the LAPS SH analysis used in this study are discussed below, including the background setup, boundary layer moisture module, GOES radiance algorithm, rawinsonde data, GVAP adjustment and data source, cloud analysis and QC.

2.1 *Background Setup*

Like most analysis systems, LAPS needs a starting point which it later modifies by adding information from other datasets. This background or first-guess field for this test is FSL's Mesoscale Analysis and Prediction System (MAPS) analysis. Updated each hour, MAPS is equivalent to NCEP's Rapid Update Cycle (RUC-2). The background model moisture data are interpolated to the denser LAPS grid and reconciled with the LAPS temperature analysis to avoid supersaturation.

2.2 *Boundary Layer Moisture*

The boundary layer moisture module utilizes surface humidity and mixes this into the calculated

* *Corresponding author address*: Daniel Birkenheuer, NOAA FSL, R/E/FS1, 325 Broadway, Boulder, Colorado 80303; e-mail birk@fsl.noaa.gov

boundary layer to improve the tracking of low-level moisture. Typically, the GVAP adjustment to column moisture is prevented from modifying the boundary layer moisture.

2.3 *Variational Adjustment using GOES Radiances*

The variational adjustment using GOES radiances has undergone prior tests and is documented (Birkenheuer 1999). For this experiment, the moisture module used GOES-8 radiances from image data available from our GVAR groundstation. These data are similar to the type of radiance data used by LAPS in the current operational AWIPS build (4.2) for adjusting upper-level moisture to GOES channels 3, 4, and 5 (the moisture, window, and dirty window channels, respectively). This setup was chosen to simulate the LAPS environment in AWIPS.

2.4 *Other Adjustments*

Another configuration for the LAPS runs presented here is the use of cloud saturation. Cloud data were taken from the LAPS cloud analysis, which further relied on satellite image data in addition to Doppler radar, ACARS, surface-based observations of sky conditions, and pilot reports. These data were used to define clear fields of view for the variational adjustment and for saturating the atmosphere in cloudy regions.

2.5 *RAOB Data*

Rawinsonde data were disabled from these runs because they were used to validate the results. Typically LAPS uses RAOB data, but for this experiment, they were not used directly by LAPS to avoid conflict. Figure 1 shows the domain and RAOB sites used in this evaluation.

2.6 *GVAP Adjustment*

LAPS water vapor profiles are scaled up or down depending on the ratio of LAPS to GVAP total precipitable water. These ratios are computed at coincident cloud-free LAPS gridpoints that intersect GVAP locations. A two-dimensional, smoothed analysis of scaling factors is then computed for the domain from this dataset of ratios. The product of this analyzed scalar field, with the moisture field at each vertical level, produces an adjusted LAPS moisture analysis. This technique preserves vertical structure and distributes the moisture change so that no single layer is modified to a large degree.

If scaling increases the moisture above saturation at some level, that moisture value is limited to saturation. At this time, the algorithm is not iterative. A possible improvement repeats the adjustment, in the case of profile saturation, in order to increase the moisture at nonsaturated levels, since it would be unlikely that saturation-limited scaling would completely satisfy the moistening requirements in one iteration. Furthermore, saturation implies cloud formation within the analysis. GVAP data are generally only available in cloud-free regions, but saturation can still occur in scaling fields some distance away from GVAP locations. At this time, no mechanism adjusts the field with iterative methods or resolves analysis-generated cloud discrepancies.

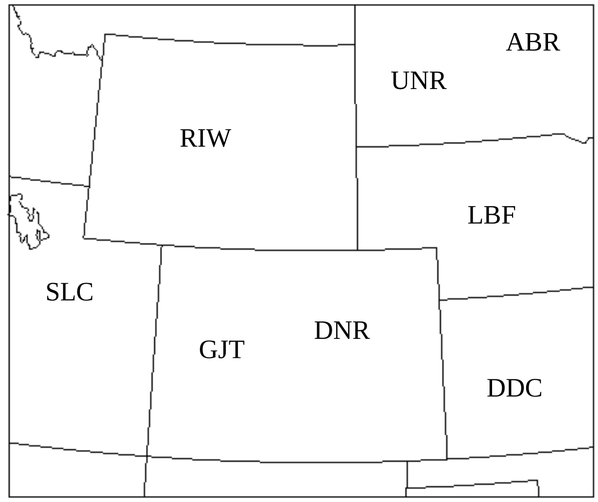

Fig. 1 The LAPS Regional Observation Cooperative (ROC) domain and the eight RAOB sites used in this evaluation.

2.7 *Cloud Saturation*

The moisture analysis is kept in agreement with the LAPS cloud analysis to make sure that the air is saturated in cloudy areas regardless of the GOES-derived scaling changes. This is performed as a near-final step in the moisture analysis.

2.8 *Quality Control*

The final step in the SH algorithm is quality control. Each moisture value is compared to the LAPS analyzed temperature, and if supersaturated, it is reported and reduced to saturation. Typically, supersaturation rarely occurs.

3. GVAP DATA SOURCE

GVAP data were obtained from the University of Wisconsin - Madison in real time on a daily basis (Menzel et al. 1998). Specialized modules for LAPS read these data and scale LAPS moisture profiles to fit the GVAP water values.

4. IMPACT STUDY RESULTS

Two runs were performed each day for the 1200 UTC data that were identical in all respects except that in the second run, the GVAP step was skipped entirely, thus no scaling was done to the moisture profile. The fact that this test was performed in delayed real time assured that the runs were identical in all respects except for the presence or absence of the GVAP algorithm.

RAOB data from all available stations in the LAPS operational area were used in validating moisture profiles. When RAOB data were not at an exact LAPS level they were linearly interpolated to that level. Approximately eight RAOBs were available per run and their use in validation was limited to the RAOB height and reporting reliability.

The statistic describing analysis quality, relative bias, is defined as the ratio of the true bias (the difference between the analyzed and observed moisture) to the observed moisture. The dimensionless relative bias is useful for describing improvements in regions where total moisture is low. The mean relative bias is similar to traditional bias error in that a positive bias value indicates that the LAPS analysis is too moist with respect to the observation.

The experiment was set to run from mid-May until mid-September 1999. Approximately 900 RAOBs were accumulated for the exercise in this time span. RAOB data from 1200 UTC were primarily used here since the GVAP schedule was difficult to match with the 0000 UTC RAOB time.

Figure 2 shows the relative bias error at each LAPS level and the corresponding number of observations. GVAP moisture data reduced bias in most layers. Low-levels were not affected or improved by GVAP data probably because the LAPS hourly surface analysis influences the low levels. Generally, infrared sounder data are more sensitive to upper-level conditions than the boundary layer, and low levels also had fewer data on average. Furthermore, this experiment was conducted at 1200 UTC posing the most difficulty for satellite observation at low levels. Also, high-level moisture analysis (100 to 500 hPa) has already been impacted (prior to GVAP application) by use of variational satellite methods. Hence, the relative bias maximum is noted at 500 hPa where the variational method stops. It is assumed that given the removal of the variational technique, GVAP would also improve bias above 500 hPa (as it does here), but the relative bias magnitude would monotonically increase with height in both the GVAP and non-GVAP runs.

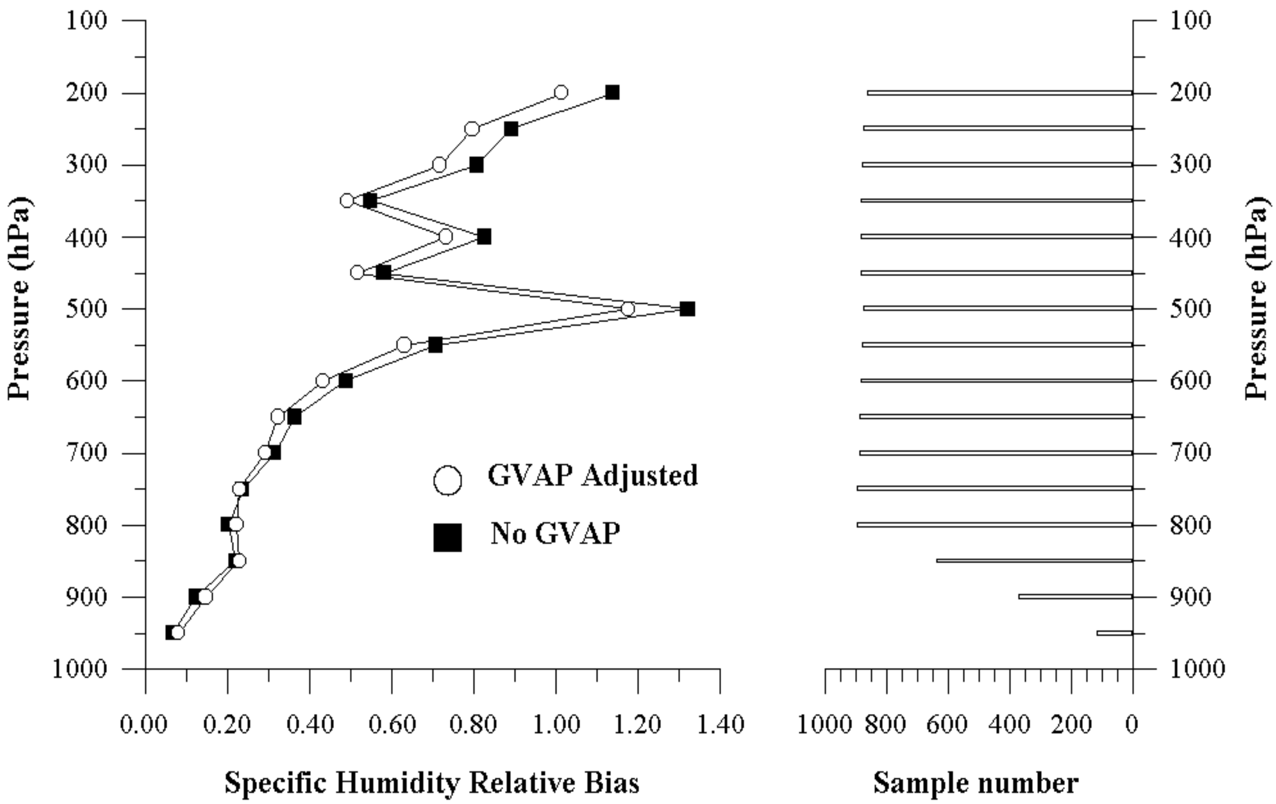

Fig. 2 Plot of relative bias and sample size with level showing positive results of GVAP data.

5. SUMMARY AND RECOMMENDATIONS

GVAP data were demonstrated to offer positive value to the LAPS moisture analysis, even in data-rich areas such as the Colorado LAPS Regional Observation Cooperative domain. Here GVAP complements traditional data sources (such as surface and model information) and supplements advanced techniques currently implemented in AWIPS, such as multichannel GOES adjustments to the upper levels of the LAPS moisture analysis.

Also significant is that GVAP improvement is seen after applying all current AWIPS-LAPS moisture adjustments including the use of image data to correct upper level moisture. This preliminary study substantiates our belief that GVAP data in the operational AWIPS LAPS system would benefit forecasting.

An obvious extension of this work will be to utilize the three other GVAP levels available. Also, provisions should be made to handle cloud formation if they occur as a result of the adjustment; generated clouds should be reconciled with the LAPS cloud analysis.

GVAP data should be provided operationally to the AWIPS field sites so they can be incorporated into LAPS and also used subjectively on their own. These data appear to be robust and contribute useful information that complement other advanced data sources.

6. REFERENCES

Birkenheuer, D., 1999: The effect of using digital satellite imagery in the LAPS Moisture Analysis. *Wea. Forecasting*, **14**, 782-788.

McGinley, J. A., S. Albers, and P. Stamus, 1991: Validation of a composite convective index as defined by a real-time local analysis system. *Wea. Forecasting*, **6**, 337-356.

Menzel, W. P., F. C. Holt, T. J. Schmit, R. M. Aune, A. J. Schreiner, G. S. Wade, and D. G. Gray, 1998: Application of GOES-8/9 Soundings to weather forecasting and nowcasting. *Bull. Amer. Meteor. Soc.,* **79**, 2059-2077.

Snook J. S., P. A. Stamus, J. Edwards, Z. Christidis, and J. A. McGinley, 1998: Local-domain mesoscale analysis and forecast model support for the 1996 Summer Olympic Games. *Wea. Forecasting*, **13**, 138-150.