P2.15 PRELIMINARY RESULTS FROM POLAR-ORBITING SATELLITE DATA ASSIMILATION INTO LAPS WITH APPLICATION TO MESOSCALE MODELING OF THE SAN FRANCISCO BAY AREA

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1. INTRODUCTION

Lockheed Martin Missiles & Space (LMMS) is pursuing research into the retrieval of advanced data products derived from polar-orbiting meteorological satellites for enhanced mesoscale cloud and moisture analyses and subsequent numerical weather prediction forecasts. In cooperation with the Department of Meteorology at San Jose State University and the National Oceanic and Atmospheric Administration's Forecast Systems Laboratory (FSL), LMMS scientists at the Center for Remote Environmental Sensing Technology (CREST) are evaluating the utility of high-resolution, satellite-derived moisture data on mesocale forecasts. Moisture fields retrieved from the Advanced Very High Resolution Radiometer (AVHRR) and microwave moisture sounders are integrated into analysis and forecast fields generated by the Local Analysis and Prediction System (LAPS), developed by FSL, and the Fifth Generation Mesoscale Model (MM5), developed jointly at the Pennsylvania State University (PSU) and the National Center for Atmospheric Research (NCAR), respectively.

Modern computer technology developed in the last decade makes it now feasible to fully utilize the volumes of remotely sensed data collected from meteorological satellite systems in operational, mesoscale forecast models. Early experience with the incorporation of remotely sensed temperature profiles into large-scale numerical weather prediction models demonstrated the importance of satellite data assimilation on forecast accuracy. Along with global coverage, low earth orbiting satellites have the advantage of being able to carry microwave instruments. Retrieval in the microwave spectral region is critical to obtaining the vertical structure of atmospheric temperature and water vapor.

This paper gives a brief description of the LAPS system as implemented in CREST and shows preliminary results from AVHRR visible and infrared data assimilation into the LAPS cloud analysis. It also discusses both the retrieval of remotely sensed cloud analyses from spectral signatures in multiple sensors carried by polar-orbiting meteorological satellites, and a new approach to incorporate these data into both LAPS and MM5 mesoscale models. The impact of these data on mesoscale forecasts will be presented in a future paper.

2. IMPLEMENTATION OF LAPS IN CREST

LAPS is a fully integrated, meso-beta-scale data assimilation and analysis system designed to handle all types of meteorological observations (described by McGinley 1989 and McGinley et al. 1992). It uses an effective analysis scheme to harmonize high resolution temporal and spatial data onto a regular grid, producing hourly surface and upper air atmospheric variables that can be used by operational forecasters to both assess current conditions and provide initial or boundary conditions for a local forecast model.

The LAPS cloud analysis (described in Albers et al. 1996), uses 10.8µ infrared, and 0.62µ visible satellite data, surface observations, aircraft reports and radar data, along with model first guess fields. Consistent three-dimensional cloud water and cloud ice analyses are derived using a modified Smith-Feddes (Haines et al. 1989) model. For each gridpoint with a cloud fraction > 0.65, cloud liquid water and cloud ice are analyzed. For thin clouds with a fraction of < 0.65, cloud condensate is estimated by considering cloud drop/ice crystal diameter and optical cross-section. LAPS is being configured in CREST to use polar-orbiting satellite data to augment the data stream while providing valuable cloud cover and vertical structure information to improve subsequent analyses.

The CREST laboratory was established in 1990 to serve as a testbed for satellite data retrieval algorithms and data processing for polar-orbiting satellites. The primary function of CREST is to support the National Polar-orbiting Operational Environmental Satellite System (NPOESS) program with the development of the Integrated Weather Product Testbed (IWPTB). The CREST Lab computer network consists of 13 UNIX workstations, eight of these are Dec-alphas running Digital UNIX 4.0d. A variety of forward models, sensor models, satellite hardware models, and retrieval algorithms are also resident in CREST providing system engineers with the capability to perform end-to-end system-level simulations. Visualization environments include but are not limited to: Vis5d, NCAR Graphics, IDL, and an extensive network of AVS/Express modules.

LAPS is currently running its ingest and analysis functions on a 400mhz Dec-Alpha workstation with 1 GB of RAM. The LAPS fields reside on a 100 x

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80, 10km horizontal resolution domain centered on Sunnyvale, California, with 21 isobaric levels at 50 mb vertical spacing. The LAPS domain and local terrain are shown in Fig. 1.

The tracking, ingest, and processing of satellite data are performed automatically and in real time using NOAA-12, 14 and 15 data collected by the CREST High Resolution Picture Transmission (HRPT) ground station. A 1-km resolution, 1024 x 1024 pixel scene of AVHRR imagery, with 10-bit accuracy, is navigated from a full swath of each pass. Automated cloud analysis algorithms (Hutchison et al. 1995, 1997) are executed on this intermediate dataset which consists of calibrated imagery, TOVS, and orbital data. These automated algorithms employ threshold functions that vary with environmental conditions in which a cloud is found, i.e., functions vary with solar zenith angle and scattering phase functions for visible and near-IR channels and with total integrated water vapor for long-wave IR channels. Software has been developed to geolocate and register these cross sensor data with each other, and to the LAPS grid. Discussions here are with standard visible 0.62μ and infrared 10.8μ AVHRR data in place of GOES data normally used in the LAPS analysis system. To make use of the LAPS moisture fields in MM5, the LAPS analysis containing satellite data is used as the first boundary condition. The remaining boundary conditions are provided by the Eta model with the initial conditions provided by a previous LAPS analysis.

3. APPROACH

Some regions of the U.S. enjoy data-rich environments, including extensive profiler, surface, and Doppler radar networks. One of these regions is Colorado where LAPS has been running operationally at FSL for nearly ten years. It is suggested that polar-orbiting data, especially microwave sounding data, can provide high spatial and (with several satellites) high temporal resolution of both temperature and moisture profiles, as well as cloud cover and cloud type information into both LAPS and any forecast model. This type of system can be particularly useful in areas that do not have profiler networks and in polar regions, where satellite passes are frequent but surface data are sparse.

The LAPS moisture analysis (Birkenheuer 1994) also depends heavily on satellite data, as well as on surface data. Satellite retrievals also provide estimates of total precipitable water. With knowledge of the near surface moisture and its vertical distribution defined by the background field, moisture can be partitioned into vertical layers. Also contributing is the cloud analysis output which can further identify saturated air and thus contribute to better definition of the moisture field (Birkenheuer 1996).

Architecture has been developed to make use of imagery data, microwave data and infrared sounder data from polar-orbiting satellites to derive high resolution cloud characteristics. This dataset consists of single sensor products, such as imagery and temperature profiles, and cross sensor products, such as cloud mask and cloud top height. These products when combined into a single database have the potential to provide valuable cloud and moisture information for atmospheric analysis and forecasts. For example, infrared sounder data when combined with imagery can provide cloud location and layer information which can then be combined with microwave data to evaluate cloud base height. Several intermediate products of this type (e.g. cloud top pressure, cloud top height, cloud mask and total integrated water vapor, etc.) are produced with each TIROS pass in CREST. Enhancements to existing analysis algorithms will be needed so they can accept the new intermediate products as input.

4. CASE STUDY

The case study presented is 2300 UTC Thursday 05 August 1999. The satellite data are from a NOAA-14 pass, with a peak elevation of 87.75°. The Channel 1 (0.62μ) and Channel 4 (10.8μ) calibrated imagery was geolocated to the LAPS grid. Each pixel value was then averaged with the eight surrounding pixels to provide slightly smoother brightness temperature and albedo values on the much coarser LAPS grid. The Eta 1200 UTC run provides the first guess fields with METAR surface observations used to provide valuable sky cover information. The synoptic pattern included a summertime cut-off low at 500 mb, which usually provides interesting vertical and horizontal cloud structure. Low stratus along the central California coast, midlevel altocumulus, cumulus and cirrus are all present in the image. Fig. 2 shows a false color enhanced satellite image using the 0.87μ, 10.8μ and 12.0μ channels. This type of enhancement is used to highlight the spectral characteristics of the cloud and land features. The 0.87μ channel has both thermal and visible characteristics that help to distinguish between land and water while the 10.8μ and 12.0μ channels are used to distinguish optically thin cirrus clouds from low and midlevel optically thicker clouds. Fig. 3 shows the LAPS column maximum cloud cover (lcv) product derived from the 3-D cloud analysis. Comparing Fig. 2 and Fig. 3 shows that LAPS makes positive use of AVHRR brightness temperature and albedo values. Fig. 4 shows the final LAPS 3D analysis. The fields displayed are surface air temperature over terrain, surface winds, cloud liquid water (light blue) and cloud ice (white). Note the lower altocumulus clouds off-shore that have been analyzed as liquid water. Preliminary results from this case and others observed show that the analyzed cloud bases and heights are consistent with satellite imagery. This is especially true in regions of higher albedo values. Lower isosurface threshold values of cloud fraction often give a better depiction of the actual cloud field using AVHRR data for this region.

5. CONCLUSION

This paper presents the system in CREST into which LAPS is implemented to interface with polar orbiting satellite data. The case presented here shows positive preliminary results in including infrared and visible AVHRR data to augment the LAPS cloud analysis. The architecture for developing a database of remotely sensed, multisensor data has been presented. Future plans are to extend this database to include Earth Observing Satellite (EOS) and NPOESS class sensor data.

Architecture that will implement the more complex cloud properties from polar-orbiting satellites into LAPS will need further development, but preliminary results to contribute useful cloud and moisture information from polar orbiting satellites into LAPS and any mesoscale model are encouraging.

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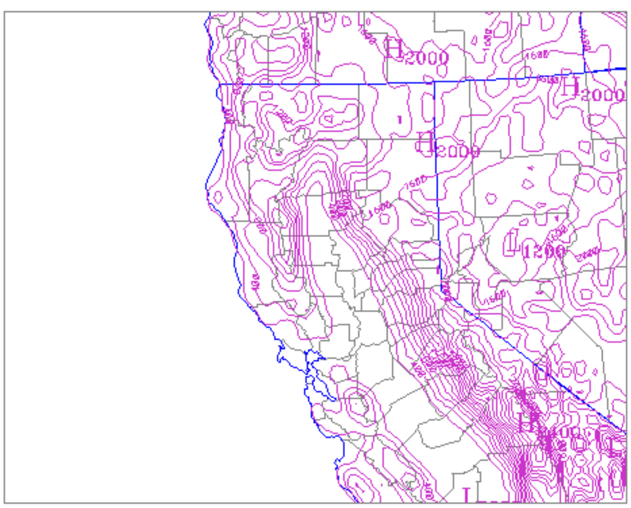

Figure 1. LAPS California domain and terrain elevation (m).

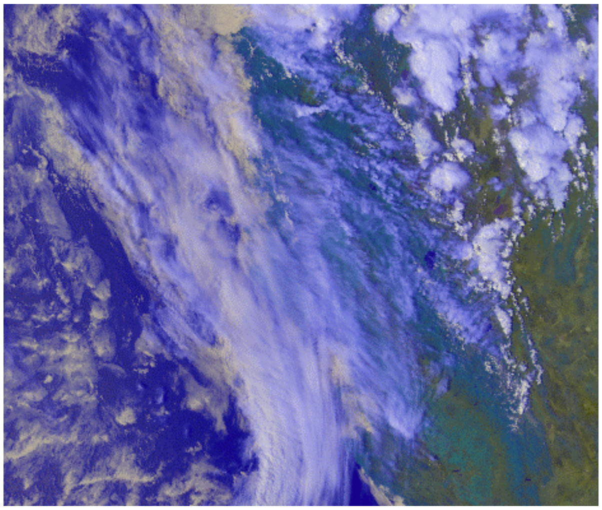

Figure 2. NOAA-14 AVHRR false color composite image using 0.87μ, 10.8μ, and 12.0μ bands.

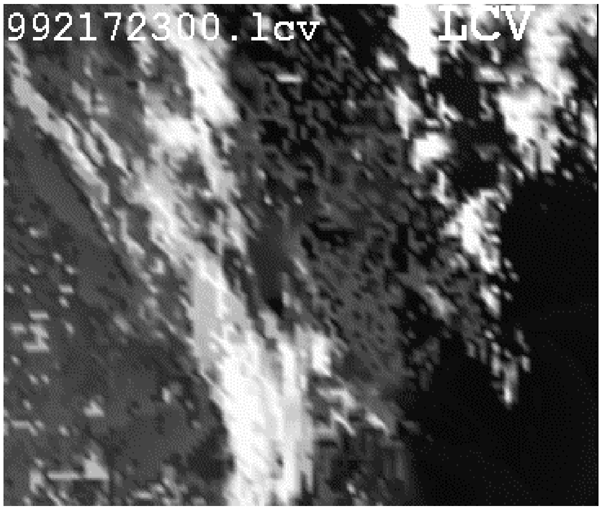

Figure 3. LAPS column maximum cloud cover values (lcv) for 2300 UTC 05 August 1999.

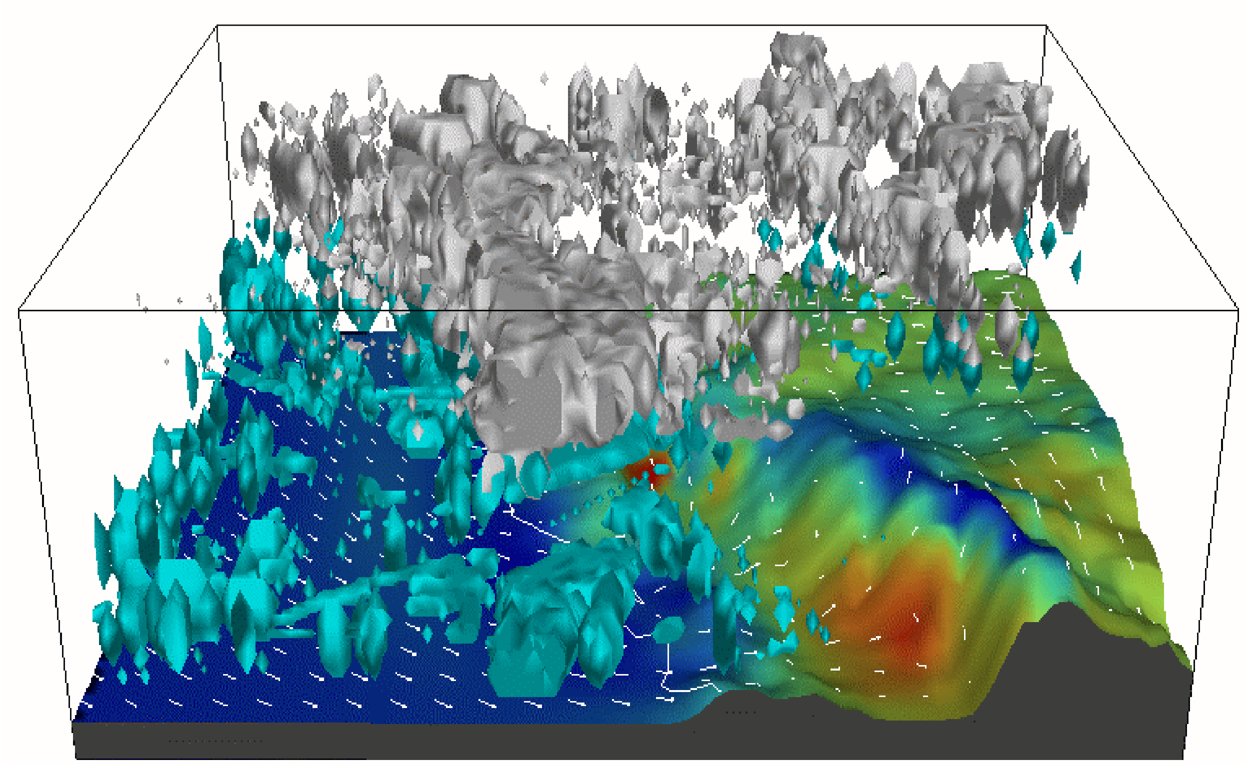

Figure 4. Final LAPS 3D analysis of cloud liquid water (lt. blue), cloud ice (white), surface winds (white vectors) and surface air temperature (surface color shading). The California coastline is also drawn white.