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Estimating the Height of the Planetary Boundary Layer for Diffusion-Transport Models: A Four Algorithm Comparison

Robert L. Russ

ESTIMATING THE HEIGHT OF THE PLANETARY BOUNDARY LAYER FOR DIFFUSION-TRANSPORT ATMOSPHERIC MODELS: A FOUR ALGORITHM COMPARISON

THESIS

Robert L. Russ, First Lieutenant, USAF

AFIT/GM/ENP/99M-09

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Table of Contents

Page

List of Figures

List of Tables

Table Page

Table Page

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Abstract

Diffusion-Transport (D-T) modeling is a branch of numerical weather prediction concerned with eddy diffusion of particulate pollutant plumes and their transport by the wind. When conducting D-T modeling, establishing the height of the planetary boundary layer (PBL) is crucial to defining the vertical bounds within which a plume can become thoroughly mixed. The PBL can be deduced from observations or model simulation.

Three sounding analysis PBL algorithms were considered—the Potential Instability Mixing Depth (PIMIX), Potential Temperature (POTEMP), and Gradient Richardson Number (RICH) algorithms. A turbulent kinetic energy (TKE) based PBL algorithm was also evaluated. The purpose of this research was threefold. First, observed atmospheric soundings were input, and algorithm output was compared to human analyses of the observed soundings (Analysis). Second, Regional Atmospheric Modeling System (RAMS) generated forecast soundings were input, and algorithm output was compared to human analyses of the forecast soundings (Simulation). Finally, algorithm output from simulation was compared with human analyses from analysis (Verification). These PBL comparisons were put into one of four categories: (1) hit, (2) indication of deep convection, (3) miss, or (4) algorithm failure. Algorithm performance was ranked based on the number of hits, then on indications of deep convection.

PIMIX was the best analysis tool, while both POTEMP and TKE were the best simulation methods. All algorithms had a similar number of hits for verification, but PIMIX had more estimates indicative of deep convection, so was ranked best.

ESTIMATING THE HEIGHT OF THE PLANETARY BOUNDARY LAYER FOR DIFFUSION-TRANSPORT ATMOSPHERIC MODELS: A FOUR ALGORITHM COMPARISON

1. Introduction

a. Background

Diffusion-Transport (D-T) modeling is a branch of numerical weather modeling primarily used to estimate the spread of various chemical and particulate pollutants by both eddy diffusion and transport by the wind. Within D-T modeling, determining an accurate height of the planetary boundary layer (PBL)--also known as the height of the mixed layer--is necessary for resolving the vertical bounds within which a chemical or particulate plume can become thoroughly mixed, as well as to determine which wind levels can contribute to transporting these plumes. This type of modeling is rarely employed for operational purposes. It is, instead, used to simulate past events or hypothetical scenarios with a relatively primitive plume type model (e.g. Sykes et al. 1986; Sykes et al.1993). Methods used to determine PBL heights for these models tend to rely on the analysis of observed conditions. However, recent advancements in coupling advanced mesoscale models to plume models has allowed for high resolution simulation of pollution environments, requiring the use of algorithms relating the output of the mesoscale model to PBL heights needed by the plume model. The two categories of PBL algorithms important for this research are sounding analysis methods and turbulent kinetic energy (TKE) methods.

Sounding analysis methods rely on observed or forecasted thermodynamic profiles to objectively determine the PBL height. Typically, analysis methods relying on observed data can only determine PBL heights twice a day--at the 0000 UTC and 1200 UTC upper air reporting times, provided such data exists near the area of interest. Another complication arises because upper air reporting times rarely occur at the optimum times of sunrise and sunset—when PBL heights are at their theoretical lowest and highest values, respectively (Kaimal et al. 1976). For this reason, mesoscale numerical models are now often used to predict PBL evolution throughout the period of interest, to ensure both the maximum and minimum PBL heights are computed for each time period. Because most mesoscale models do not explicitly output PBL heights, sounding analysis algorithms are often used on forecasted soundings in an effort to determine PBL heights. However, forecasted soundings from mesoscale models differ from observed soundings in that model soundings represent areal averages of the thermodynamic variables. This affects the accuracy of methods designed for use with observed soundings and suggests using model-derived methods may yield better results.

One such method utilizes TKE. Within the boundary layer, TKE is relatively high, while in the free atmosphere, TKE is relatively low (Mason 1989). The top of the PBL can be defined as the height where TKE first becomes low. Since TKE cannot be easily measured or observed by radiosondes, TKE can't be used as an analysis tool. However, TKE is often output directly, or derived from mesoscale models.

The Air Force Technical Application Center (AFTAC) routinely performs D-T modeling over data poor or data denied areas. AFTAC uses the Short Range Layered Atmospheric Model (SLAM) (Capuano et al. 1997) with either observed input data or data fed by the Regional Atmospheric Modeling System (RAMS) (Pielke et al. 1992; Walko et al. 1993) mesoscale model. RAMS ingests the 2.5 degree data from the NCEP/NCAR Reanalysis Project, as well as synoptic soundings and surface data (Appendix A). SLAM contains three different sounding analysis algorithms for computing PBL heights—the Potential Instability Mixing Depth (PIMIX), Potential Temperature (POTEMP), and Gradient Richardson Number (RICH) algorithms (Capuano et al. 1997). AFTAC also uses a post-processing program that computes PBL heights from RAMS gridded TKE fields as an alternate input for SLAM (Appendix B). These different algorithms have never been objectively compared to each other; however, PIMIX and POTEMP were subjectively compared to each other by Kienzle and Masters (1990), where it was determined that PIMIX generated higher PBL estimates in tropical environments than POTEMP, but both generated similar PBL estimates in drier environments. Furthermore, none of the algorithms have been compared to human-analyzed soundings, nor have their performances on forecasted soundings been determined.

b. Problem and Objective

There are three basic questions which AFTAC required answers to regarding PBL heights in its D-T modeling efforts, each of which comprises a separate part of this research.

- Which of the three SLAM algorithms, when ingesting observations, is most accurate when compared with observed soundings? (Analysis)

- Which of the four algorithms (three SLAM algorithms plus the TKE method), when input with RAMS forecast data, is most accurate when compared to the RAMS forecast soundings? (Simulation)
- Which of the four algorithms, when used with RAMS forecast data, is most accurate when verified against observations? (Verification)

Answering the analysis question requires a comparison between the output of the three SLAM algorithms and an objective standard. Human-analyzed soundings will be used for this standard and will be considered the observed "truth." The simulation question will be answered by comparing the output of the four algorithms with human-analyzed RAMS generated soundings, taken to be the simulated "truth." Finally, the verification question will be answered with a comparison of the different algorithms with the observed truth from the analysis. The simulated "truths" were also verified with the human-analyzed observed soundings for comparison purposes.

c. Importance of Research

1) Analysis

This research will enable AFTAC to determine the best algorithms to use for analysis and prediction of PBL heights in their D-T modeling efforts, and how this differs by geographic weather regime. Because they routinely tackle problems in data poor or data denied areas, they have been unable to gather more than a subjective feeling for the merits of the different algorithms. The results of this research allow AFTAC to use the best algorithm for the given conditions, increasing the accuracy of their simulations.

2) Simulation

This research will provide AFTAC an understanding of which PBL predictive algorithm works best in the modeling environment. This allows them to choose the best forecasting algorithm for the many different weather regimes they encounter. Also, they will learn which algorithm to choose as improvements are made to their mesoscale modeling efforts.

3) Verification

This research will demonstrate to AFTAC the best verifying model-algorithm setup for their simulation efforts. Because of their lack of verification data, AFTAC has been unable to objectively describe the inherent limitations and accuracy of their D-T modeling. The results of this research assist AFTAC to maximize the accuracy of their modeling efforts.

d. Summary of Key Results

The PBL estimates from the algorithms were compared to the appropriate standards and were placed into one of four categories: (1) a hit, (2) an indication of deep convection, (3) a miss, or (4) an algorithm failure. The algorithms' performances were ranked based on which algorithm had the statistically significant greatest number of hits. If two or more algorithms had a statistically similar number of hits, then the algorithm with the greatest number of estimates indicative of deep convection was ranked better. The following results were obtained.

1) Analysis

Overall, PIMIX had the greatest number of hits, and RICH had the fewest number of hits. Furthermore, PIMIX was equal to or superior to any other algorithm in the number of hits for each weather regime defined in this research. POTEMP had as many hits as PIMIX in dry environments, but had many misses in areas with moist convection.

2) Simulation

Overall, POTEMP and TKE were similarly accurate and had at least as many hits as the other algorithms in all regimes. PIMIX had the most estimates indicative of deep convection, but appeared to be too sensitive to moisture and consistently overestimated PBL heights in moist environments, resulting in fewer hits. However, it performed equal to POTEMP and TKE in dry regimes. RICH had the fewest number of hits.

3) Verification

All three algorithms exhibited the same performance, with a similar number of hits. However, PIMIX had more PBL estimates indicative of deep convection, which made it better than the other algorithms.

e. Thesis Organization

Chapter 2 presents a general description of PBL theory, the three SLAM algorithms, and an overview of TKE theory, as used in this research. Chapter 3 presents the experimental set-up and methodology, while Chapter 4 presents the statistical analyses and results. In Chapter 5, conclusions and recommendations are made. Chapter 5 also contains recommendations for further research.

2. *Theoretical Background*

a. Overview

This chapter presents a short review of PBL theory, describes the three SLAM algorithms, and reviews the theory behind TKE derived PBL heights. This only presents an overview of the material, with emphasis on areas pertinent to the research.

b. The Planetary Boundary Layer (PBL)

The PBL is loosely defined as that region of the lower atmosphere where the effects of turbulent eddies are important. These eddies range in size from less than a meter across for wake eddies, to ≈10 km across for deep convective eddies that penetrate to the tropopause. The major identifying feature of the PBL is that it is thoroughly mixed by turbulent eddies, so that potential temperature, water vapor mixing ratio, and wind velocity are conserved in the vertical (Mason 1989; Kaimal et al. 1976). The PBL is usually capped by a potential temperature inversion and is commonly seen as the feature on skew-*T* diagrams called the "inverted vee" below the inversion (Figure 1). On the skew-*T* diagram, constant potential temperature with height is indicated by the temperature trace following a dry-adiabat, while the constant mixing ratio is indicated by the dew-point trace following a mixing ratio line.

In traditional treatments of the PBL, only dry convective processes are considered. However, for the purposes of this research, moist processes will also be considered. In the presence of moist convection, the PBL will no longer be conservative with respect to potential temperature and mixing ratio, but will instead conserve equivalent potential temperature within convective clouds. Thus, when moist processes are present, the PBL on a skew-*T* diagram will show the influences of both dry and moist

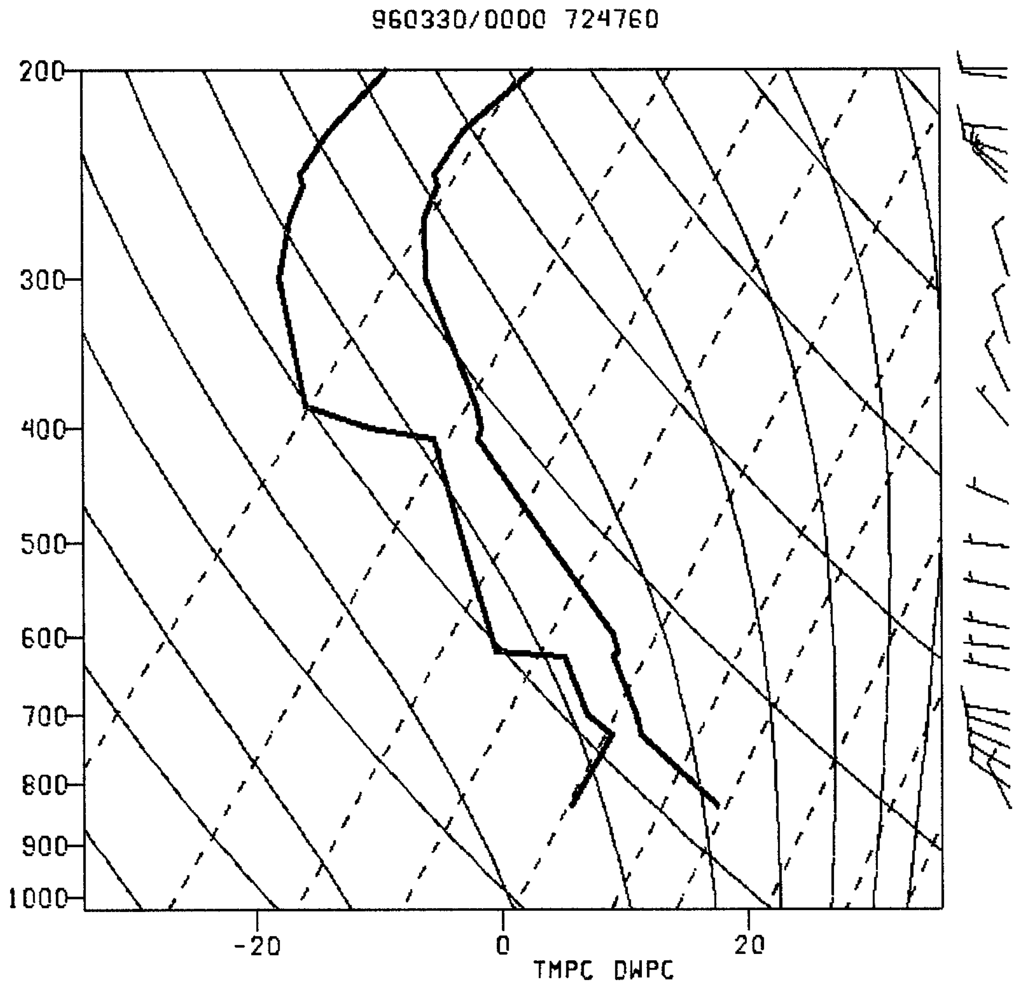


FIGURE 1. Inverted Vee. A representative skew-*T* showing the "inverted vee" indicative of the PBL.

processes (e.g. the temperature trace will follow a dry-adiabat below cloud base and a moist-adiabat within convective clouds). In a deep convective environment, the PBL will be defined as the near surface layer where potential temperature and mixing ratio are constant with height up to cloud base, from where equivalent potential temperature is constant with height. However, it must be understood this definition differs from the traditional definition of the PBL, and that the part of the PBL above cloud base (as defined for this research) may not be as thoroughly mixed as the traditional PBL is considered to be. This results because the deep, moist-convective eddies penetrate into otherwise stable air and are not as efficient at thoroughly mixing the atmosphere as the smaller, dry-convective eddies are.

In this research, forecast soundings from RAMS will be used, as will synoptic upper-air soundings. It is important to note the differences between an observed sounding and a model-derived sounding. The observed sounding is a point measurement, in that only the part of the atmosphere in contact with the sensor is actually sampled. In a convective environment, there will be vast differences between a sounding that goes through a thunderstorm and one that goes up next to a thunderstorm. The temperature profiles will be similar, but the between-cloud sounding will show the presence of small scale subsidence inversions, with associated drying. The in-cloud sounding will have a near moist-adiabatic temperature profile and will be completely saturated. A model-derived sounding will not show these small scale features, because they are not resolved. Instead, the soundings will have an areal average of both temperature and moisture parameters. This difference is important to note, because the SLAM algorithms were not designed for use with the averaged soundings of a mesoscale model like RAMS.

c. The Gradient Richardson Number (RICH) Technique

The Richardson technique used by SLAM is based on the gradient Richardson number formulation, given by the equation:

$$Ri = \frac{g}{\theta} \frac{\delta\theta/\delta z}{(\delta\bar{u}/\delta z)^2} \quad (2.1)$$

where Ri = the gradient Richardson number, g = the acceleration due to gravity, θ = the layer mean potential temperature, $(\delta\theta/\delta z)$ = the mean potential temperature gradient, $\bar{u}$ = the layer mean wind speed, and $(\delta\bar{u}/\delta z)$ = the mean vertical wind speed gradient (Capuano et al. 1997). In this formulation, Ri represents the ratio of the stability to the vertical wind shear. When Ri is less than zero, $\delta\theta/\delta z$ is less than zero, and the sounding is absolutely unstable. When potential temperature is constant with height, as it is within the sub-cloud portion of the PBL, then Ri is zero. When Ri has some positive value, then the sounding is either conditionally, or absolutely stable.

SLAM calculates Ri at 100 m intervals from the ground up to 4,000 m above ground level (AGL). The PBL height is defined as the first occurrence above the ground where Ri is greater than 10, or where Ri is greater than 1 when the temperature gradient is greater than 0.01 K m^{-1}. Like all of the SLAM algorithms, it will return a value of 100 m when it detects a ground-based inversion, and a value of –500 m when it cannot determine the height of the PBL. Also, by design, this method will never return a value greater than 4,000 m AGL, so it is determined *a priori* to be of little value in an environment of deep, moist convection.

d. The Potential Temperature (POTEMP) Technique

The POTEMP algorithm in SLAM computes PBL height by using five different potential temperature gradients ($\delta\theta/\delta z$), with five associated potential temperature differences ($\delta\theta$), as shown in Table 1 (adapted from Kienzle and Masters 1990). The algorithm identifies an inversion where the observed potential temperature lapse rate is greater than the selected $\delta\theta/\delta z$. Once an inversion level is identified, the algorithm computes the height in the inversion that is $\delta\theta$ greater than the potential temperature at its base, utilizing the following equation, as shown in Figure 2 (Kienzle and Masters 1990):

$$h_i = z_b + \frac{(z_t - z_b)}{(\theta_t - \theta_b)}\delta\theta_i \qquad (2.2)$$

where h_i = the PBL height estimate for $(\delta\theta/\delta z)_i$, z_t = top of the inversion layer, z_b = base of the inversion layer, θ_t = potential temperature at the top of the inversion layer, θ_b = the potential temperature at the base of the inversion, and $\delta\theta_i$ = the distance into the inversion associated with $(\delta\theta/\delta z)_i$. POTEMP computes five different estimates for the PBL height and searches for a discontinuity in the potential temperature lapse rate--defined as a difference of at least 200 m between successive estimated PBL heights. Equation 2.2 is then used to interpolate the PBL height using the $\delta\theta/\delta z$ and $\delta\theta$ associated with the base of the discontinuity. If a discontinuity is not found, then POTEMP assigns the PBL estimate generated by $\delta\theta/\delta z = 0.005$ K m^{-1} and $\delta\theta = 1.5$ K as its default. Table 1 shows a hypothetical case, where the discontinuity has its base at 1,087 m. The PBL

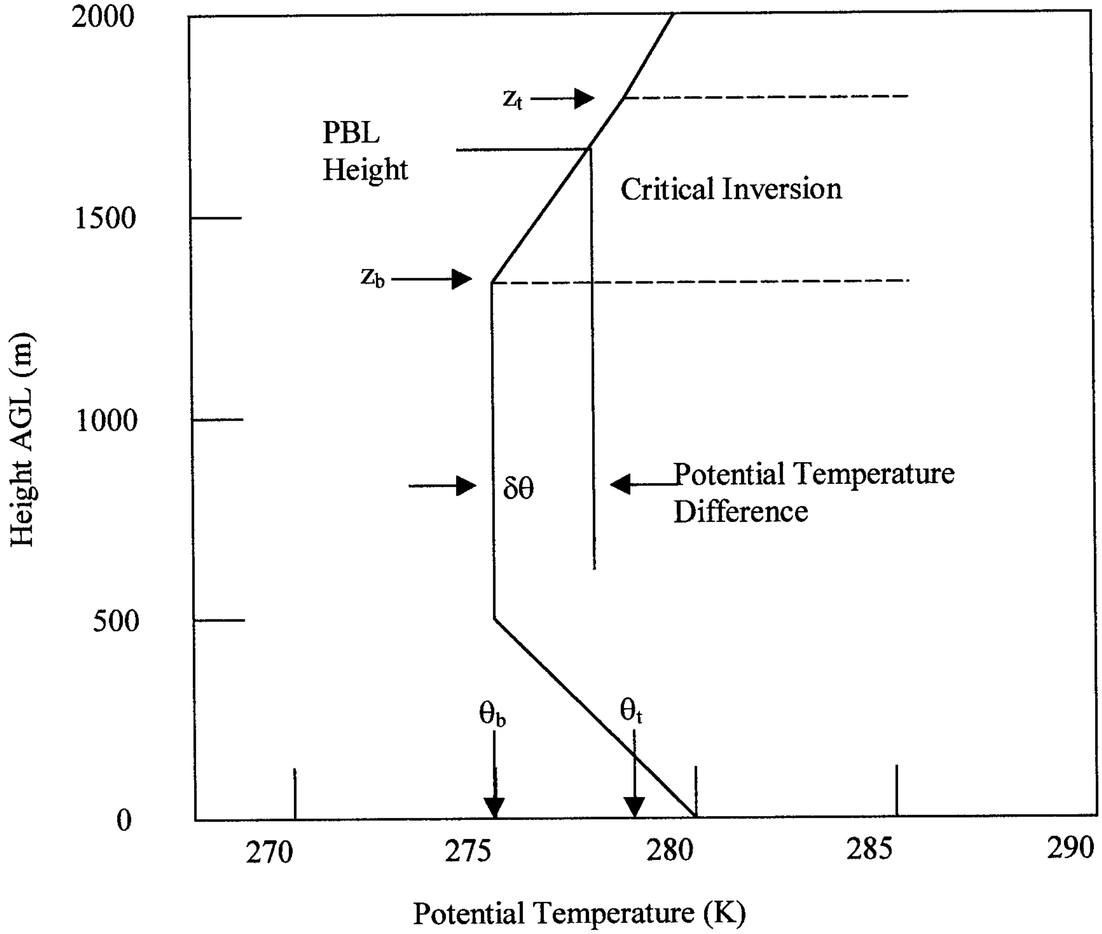


FIGURE 2. POTEMP Schematic. A graphical representation of how the POTEMP algorithm is computed. $\delta\theta$ is the potential temperature difference, θ_t and θ_b are the potential temperature corresponding to the top and bottom of the layer, and z_t and z_b are the height AGL of the top and bottom of the layer, respectively. The PBL estimate is interpolated $\delta\theta$ into the inversion (adapted from Capuano and Atchison 1985).

height would then be interpolated 1.8 K into this layer.

POTEMP is not constrained to the lowest 4,000 m AGL, as RICH is, so it can return high values of PBL height. Utilizing the five different potential temperature gradients does try to capture some of the variability of moisture, but it does not explicitly check the sounding for saturation or compare the temperature lapse rate with the moist-adiabatic lapse rate. By interpolating $\delta\theta$ into the inversion, POTEMP allows for entrainment at the top of the PBL.

TABLE 1. POTEMP Parameters. Potential temperature gradients and associated potential temperature differences used with the POTEMP algorithm, along with simulated PBL height output (adapted from Kienzle and Masters 1990).

$\partial\theta/\partial z$ (K m^{-1})	$\partial\theta$ (K)	PBL Height (m)
0.003	0.9	942
0.004	1.2	990
0.005	1.5	1039
0.006	1.8	1087
0.007	2.1	3367

e. The Potential Instability Mixing Depth (PIMIX) Technique

The PIMIX algorithm is similar to the POTEMP algorithm, except that it takes moist processes explicitly into consideration. PIMIX compares the sounding with the layer averaged moist-adiabatic lapse rate to look for the capping inversion to convection. It defines a surface-based inversion as a surface-based stable layer where the potential temperature at the surface is at least 5 K less than the top of the stable layer, or is greater than 500 m deep. Ground-based inversions less than 5 K across and 500 m deep are ignored (Kienzle and Masters 1990). If a sounding does not have a ground-based inversion, then PIMIX steps through the sounding layers until it finds a layer whose temperature lapse rate is at least 0.001 K m^{-1} less than the moist-adiabatic lapse rate computed for that layer (Figure 3). In order to calculate the moist-adiabatic lapse rate,

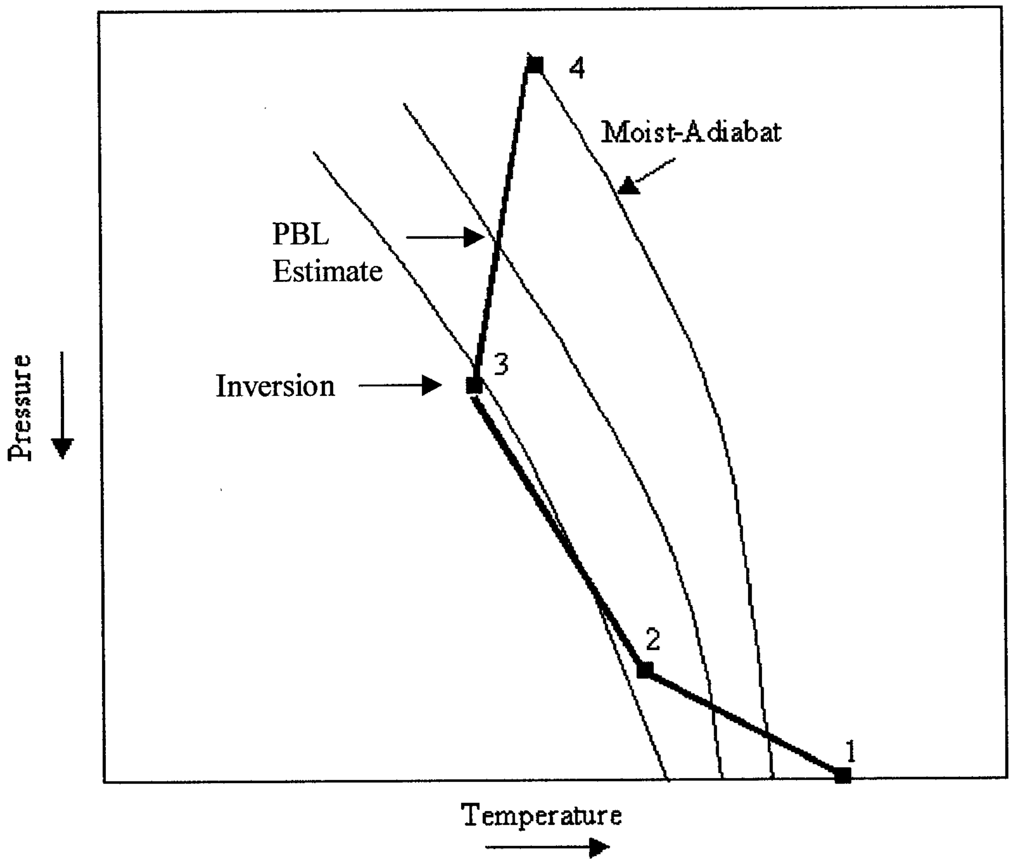


FIGURE 3. PIMIX Schematic. The numbers represent the different sounding levels. A moist-adiabatic lapse rate is computed for the center of each layer, and the observed temperature lapse rate is compared to it. The PBL estimate is interpolated 1.5 K into the inversion (adapted from Kienzle and Masters 1990).

several parameters are computed from the sounding data (Kienzle and Masters 1990). It starts with saturation vapor pressure:

$$e_s = 6.1078 \exp\left[17.26939 \frac{(T-273.15)}{(T-35.85)}\right] \tag{2.3}$$

where e_s = saturation vapor pressure and T = temperature (K). From this, it computes the saturation mixing ratio:

$$w_s = \frac{(0.62198 e_s)}{(P - e_s)} \tag{2.4}$$

Where w_s = saturation mixing ratio and P = pressure. From these quantities, PIMIX computes the moist-adiabatic lapse rate for the layer:

$$\gamma_s = \Gamma_d \frac{1 + (L w_s)/(R_d T)}{1 + (0.62198 L^2 w_s)/(R_d C_p T^2)} \tag{2.5}$$

where γ_d = moist-adiabatic lapse rate, Γ_d = the dry-adiabatic lapse rate, L = latent heat of vaporization, C_p = specific heat of air at constant pressure, and R_d = dry air gas constant. The moist-adiabatic lapse rate is averaged from the top and bottom of the layer and compared to the observed temperature lapse rate computed for the layer.

After PIMIX identifies a layer that is less than moist-adiabatic, it tests to see if the layer is sufficient to act as a cap on convection. It does this by checking the potential temperature difference across the layer. If the potential temperature difference is greater than 1.5 K, then the PBL height is defined as the height within the layer that is 1.5 K greater than the potential temperature at the base of the layer by using equation 2.2. If the layer does not meet this criteria, the algorithm continues to step upward.

PIMIX was designed to improve the estimates that POTEMP generated and has been shown to return higher values in tropical environments (Kienzle and Masters 1990). However, the goal of this research, in part, is to determine which algorithm performs best in the modeling environment produced by RAMS; and, as stated before, none of the previous three algorithms were designed to work in the modeling environment. This leads us to consider methods that are better suited to the modeling environment.

f. Turbulent Kinetic Energy (TKE)

Turbulent transport theory and how it pertains to the PBL is an extremely complicated subject, far beyond the scope of this thesis. As it pertains to this research, in the PBL, TKE is high, and above the PBL, TKE is low (Mason 1989). RAMS generates three dimensional fields of TKE using a second order Mellor and Yamada (1974) closure scheme, from which a post-processing routine computes a horizontal field of PBL heights. This post-processing program steps upward by model level at each grid point to look for the top of the PBL. The algorithm first converts the model level into an AGL height in meters, and then checks to see if the TKE value is less than 0.001 $m^2 s^{-2}$. The PBL for that grid point is then assigned as the height of the first model level where the TKE value is less than this threshold value. The code for this post-processing program is in Appendix B.

3. Experimental Setup and Methodology

a. Overview

This chapter presents the experimental setup used throughout this research. This research project is broken down into three parts called analysis, simulation, and verification. Analysis compares human-analyzed, observed soundings with the PBL estimates (for the observed soundings) output from the SLAM analysis algorithms. In simulation, RAMS forecast soundings are input to the three SLAM algorithms, and the TKE post-processing routine and their output is compared to human-analyzed RAMS forecast soundings. Verification compares the outputs of the four algorithms from simulation with the human-analyzed, observed soundings from the analysis. The methodology used to hand-analyze soundings is presented in those sections that require it.

b. Overall Setup

The mandate for this research required that a large sample size be collected to ensure statistical significance in the results. It also called for a wide selection of different weather regimes to explore possible regional differences in the results. Another concern was separating the data in time and space to avoid correlation—an unwanted complication. The project was further constrained by the realities of limited time for completion and the difficulties of hand-analyzing a large number of soundings. The experimental setup reflects a good compromise among the several governing factors.

The space domain for this research is defined by the following five upper air reporting stations (WMO# / ID / ELEV):

- Key West, Florida (722010 / EYW / 2 m)
- Lake Charles, Louisiana (722400 / LCH / 4 m)
- North Platte, Nebraska (725620 / LBF / 847 m)
- Grand Junction, Colorado (724760 / GJT / 1472 m)
- Vandenburg AFB, California (723930 / VBG / 100 m)

These stations were chosen because of their geographic separation as well as the variety of geographic regimes they represent. Key West is virtually maritime, while Grand Junction is mountainous. Lake Charles and Vandenburg represent different aspects of a coastal environment, and North Platte is high plains continental. These stations are widely separated, so they are not spatially correlated; however, it was still necessary to minimize time correlation at the individual stations.

The time domain for this research is wholly contained in calendar year 1996, but data was collected in a manner to mitigate time correlation. The data were collected every 10 days starting with Julian day 10 and ending with Julian day 360. Since RAMS would have to generate soundings, the initialization times for the model varies by 12 hours between each collection day to prevent the forecasts from always being compared to the same sounding time. For example, the initial date and time for the study is 0000 UTC 10 January 1996. For day 20, the model initialization time is 1200 UTC 19 January 1996. After initialization, RAMS makes a 24-hour forecast, generating a sounding for each station at the 0-, 12-, and 24-hour points, to compare to the local observed sounding. The resulting dataset is comprised of three observed soundings per day, for each station, and three RAMS forecast soundings per day, at each station, for 36 days, barring missing data. The 0-hour forecast soundings are not used for verification, but are used for the analysis and simulation comparisons.

c. Analysis

The SLAM algorithms estimated the PBL heights of 481 observed soundings collected from the five stations and provided by ENSCO, Inc. These same soundings were then rigorously hand-analyzed to establish the observed "truth." Each sounding was put into GEMPAK format and displayed as a skew-*T* to get an idea of the approximate height of the PBL, or to determine if a ground-based inversion existed. Then, potential temperature and equivalent potential temperature versus height were examined, along with the vertical wind profile, to locate the height of the capping inversion at the top of the PBL. The height corresponding to a potential temperature approximately 2 K greater than the base of the inversion was selected as the height of the PBL, to account for entrainment. Inversions less than 100 m in height and 5 K across were ignored (to maintain consistency with the algorithms).

All of the soundings from Grand Junction, North Platte, and Vandenburg AFB were very clear as to the thermodynamic processes occurring in the atmosphere. However, Key West and Lake Charles were not always as clear, due in large part to the tropical nature of the atmosphere at these locations, especially during the warmer months. Soundings were frequently observed with nearly moist-adiabatic temperature profiles up to the tropopause, with indeterminate dew point profiles. It was impossible to tell if deep,

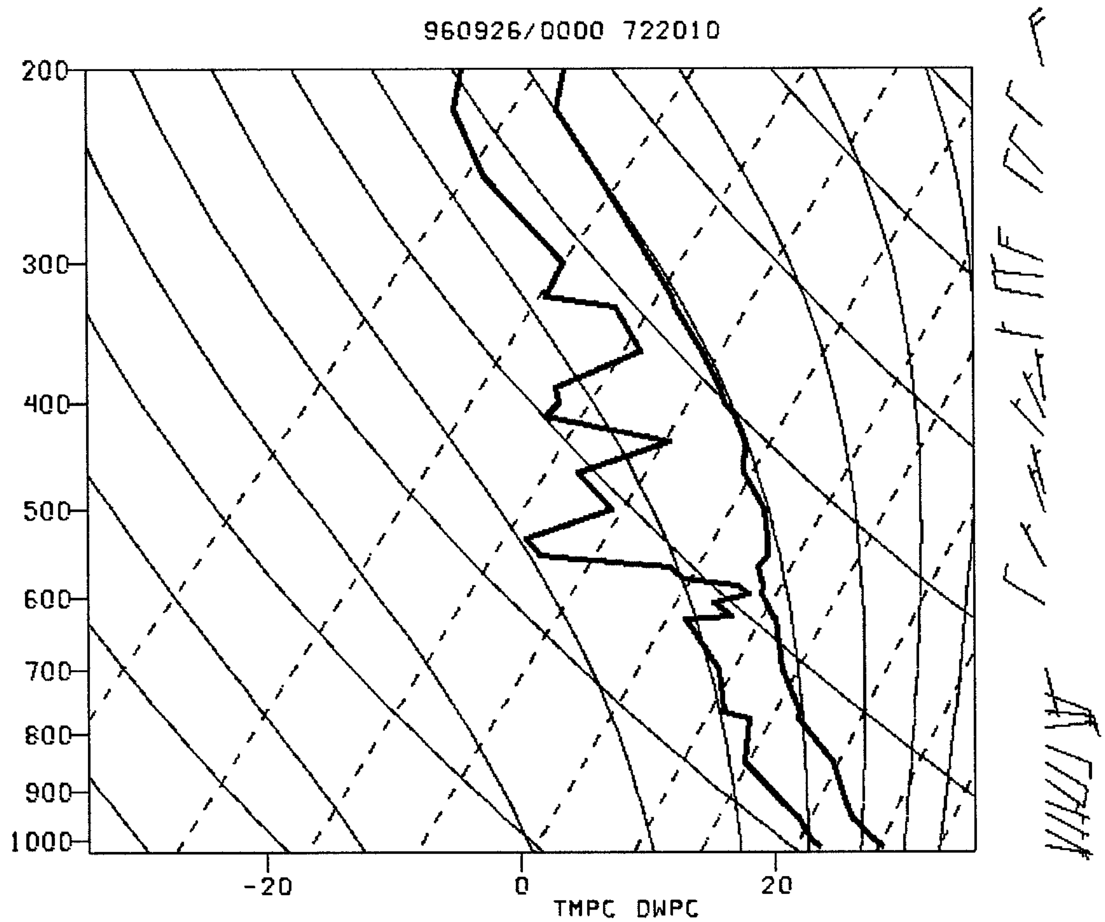


FIGURE 4: Tropical Skew-*T*. This skew-*T* shows the influence of a deeply convective environment with a moist-adiabatic temperature lapse rate and between cloud subsidence inversions. Cumulonimbus were reported at 1800 UTC.

moist convection was occurring in the region and the balloon went up next to a thunderstorm, or if the temperature profile was a remnant from the previous day's convection (Figure 4). For these two locations, surface observations were obtained from the regions, within about 250 km of the reporting stations. The observations were collected starting six hours before the first sounding each day until the last sounding of the day. This amounted to over 7,400 observations for the months of April through October. The data were sorted by (in order) present weather, 6-hour precipitation, low-cloud type, mid-cloud type, and high-cloud type. The bulk of the observations, which did not contain any of this information, were discarded. With what was left, it was possible to determine which days had deep convection, which days had moderate cumulus build up, and which had only fair weather cumulus. Armed with this information, the soundings could be properly analyzed, and the difference between an intracloud subsidence inversion and a capping inversion became apparent. A listing of the filtered observations are in Appendix C. The hand-analyzed sounding data represent the observed "truth" used for the rest of the project.

After the hand-analyses, the SLAM algorithm PBL estimates were compared to the observed "truth," and the RMS error between the two were measured. These errors were then categorized, based on their usefulness:

- Category 1: Clear "hit." Algorithm's PBL estimate is within 100 m (< 3000 m AGL) or within 250 m (≥ 3,000 m AGL) of the truth. The PBL estimate is accurate.
- Category 2 (Both PBL truth and estimate ≥ 3,000 m AGL only): Indicates deep convection. Estimate is > 250 m away from the truth, but is ≥ 3,000 m AGL. This is a "miss," but the PBL estimate is still somewhat useful, because it suggests deep convection.
- Category 3: Clear "miss." PBL estimate does not meet the criteria for Class 1 or 2. Estimate is useless.
- Category 4: Algorithm failure. Algorithm outputs –500 m indicating it could not estimate a PBL height.

These classes were established in conjunction with AFTAC personnel, based on their concepts of the usefulness of PBL estimates. Category 2 recognizes the difficulties in defining the top of the PBL in a deeply convective environment. The algorithm could perform well but still be off by 1,000 m, or more, due to the inherent noise in observed data around regions of thunderstorms. This is better performance than an algorithm that does not even recognize the presence of the convection. Also, as a quality control measure, 20 randomly selected observed soundings were analyzed by a third party meteorologist. These PBL estimates were then compared to the observed "truth" with 14 categorized in Category 1, 2 in Category 2, and 4 in Category 3. The bulk of the differences occurred in deep-convective environments, which are extremely difficult to analyze, even among meteorologists.

After the PBL estimates were compared, chi-square significance testing was performed on the categorized data. The different category counts for each algorithm were put into a contingency table, and the following hypothesis was tested for each station, as well as for the sum of all stations:

- Null Hypothesis: All three algorithms perform the same;
- Alternate Hypothesis: At least two are significantly different.

The marginal values (row totals and column totals) were computed from the observed counts; and, from these, expected count values were calculated (Figure 5). Algorithm counts are in the columns, and category counts are in the rows. For each cell in the contingency table, the row marginal was multiplied with the column marginal for that cell, and then divided by the total number of cases. If any categories had expected counts less than one, the row was dropped, and the table was reduced. This is to prevent the chi-square statistic from becoming invalid (Conouer 1980). A chi-square test statistic was then calculated by:

$$\chi^2 = \sum_i \left[\frac{(Obs_i - Exp_i)^2}{Exp_i} \right] \tag{3.1}$$

where i ranges over all cells in the contingency table. A P-value was then computed

Observed Counts

A	B	R1=A+B
C	D	R2=C+D
E	F	R3=E+F
C1=A+C+E	C2=B+C+F	

Total = TT = C1+C2 = R1+R2+R3

Expected Counts

(R1*C1)/TT	(R1*C2)/TT
(R2*C1)/TT	(R2*C2)/TT
(R3*C1)/TT	(R3*C2)/TT

FIGURE 5: Categorical Data Analysis. Algorithm counts are in the columns, and category counts are in the rows. The Observed counts are turned into marginal totals (C*i* and R*i*), which are then used to compute the expected counts.

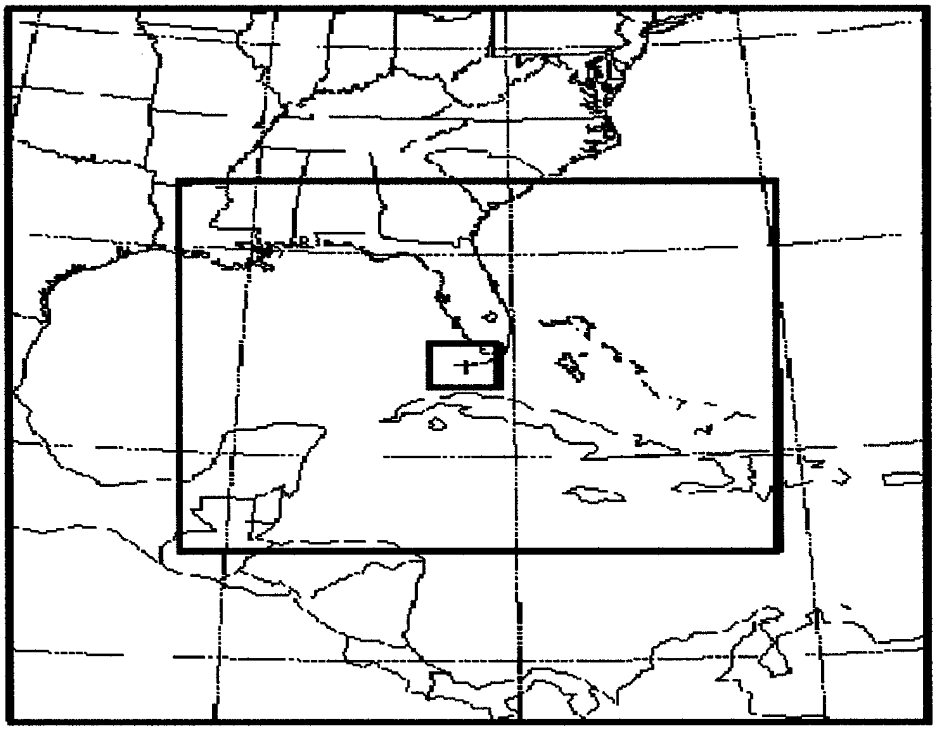
based on this chi-square value and the degrees of freedom (*df*) of the table. The *df* of a table is (number of rows-1)(number of columns-1). A statistical software package was used in the calculations, and some of the output was double-checked by hand and compared to the chi-square distribution in Table A.6 in Devore (1995). If the P-value was less than 0.005, the null hypothesis was rejected in favor of the alternate. If the P-value was greater than 0.100, the null hypothesis was not rejected. If the P-value was in between, the test was considered inconclusive. What this decision rule means is that there is only a 0.5% chance that the null hypothesis would be rejected if no difference existed between any of the algorithms.

d. Simulation

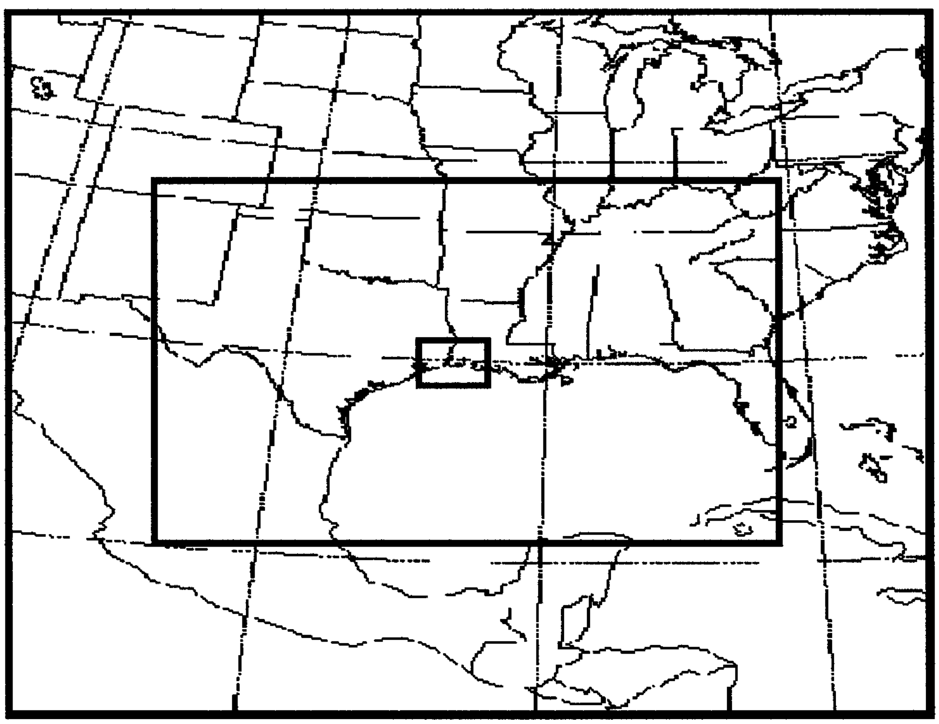
In order to forecast for the five stations in this project, the model domain for RAMS needed to be selected. Since RAMS has lateral boundaries, as well as boundaries between nested grids, several different configurations were tested per the recommendations of Warner et al. (1997), in an effort to minimize boundary induced errors, while still being consistent with AFTAC standard procedure. All configurations had some combination of three nested grids. The outer grid (grid 1) was at 100 km resolution. Grid 1 used this spacing to mesh well with 2.5° gridded data from the NCEP/NCAR Reanalysis Project. A slightly smaller 25 km resolution sub-grid, grid 2, was nested within grid 1. Within grid 2 were one or more 5 km resolution grids centered about the individual stations used for this research. Grid 2 was used to couple the low resolution data to the high resolution 5 km grids. All grids were interactively coupled and had 30 vertical levels. The levels were spaced from 100 m apart near the surface to 1,000 m apart near the top of the model, which was near 20 km in height. Some configurations were rejected because of obvious boundary induced noise resulting from the proximity of grid 2's boundary to the 5 km resolution sub-grids. Small wave-length, high amplitude gravity waves were apparent in the surface wind fields for these configurations. To resolve this problem, the boundaries of the outer grids were moved further out, resulting in much smoother wind fields.

For the final configurations used, Key West, Lake Charles, and North Platte were each centered in their own model configuration within three nested grids (Figures 6 and 7)--grid 1 at 100 km resolution, grid 2 at 25 km resolution, and grid 3 at 5 km resolution. Vandenburg AFB and Grand Junction were similarly arranged, except they shared the same grid 1 and grid 2, but had individual 5 km grids. These four configurations allowed maximum use of the computing resources, which could run four model configurations simultaneously. For further specifics of the RAMS setup, refer to Appendix A.

For each day, RAMS generated 0-, 12- and 24-hour forecast soundings. PBL height estimates were made from the forecasted soundings by the SLAM algorithms. The TKE fields were run through the post-processing program (Appendix B) to generate an additional estimate of PBL height. These forecasted height estimates were compared to those generated by hand-analyzing the RAMS forecasted soundings and categorized using the same methods in the analysis. After these data were compared, significance testing was done in the same manner as in the analysis. As a quality control measure, 18 randomly selected forecast soundings were analyzed by a third party, with nine hits and nine misses. This highlights how difficult it is to analyze forecasted soundings.

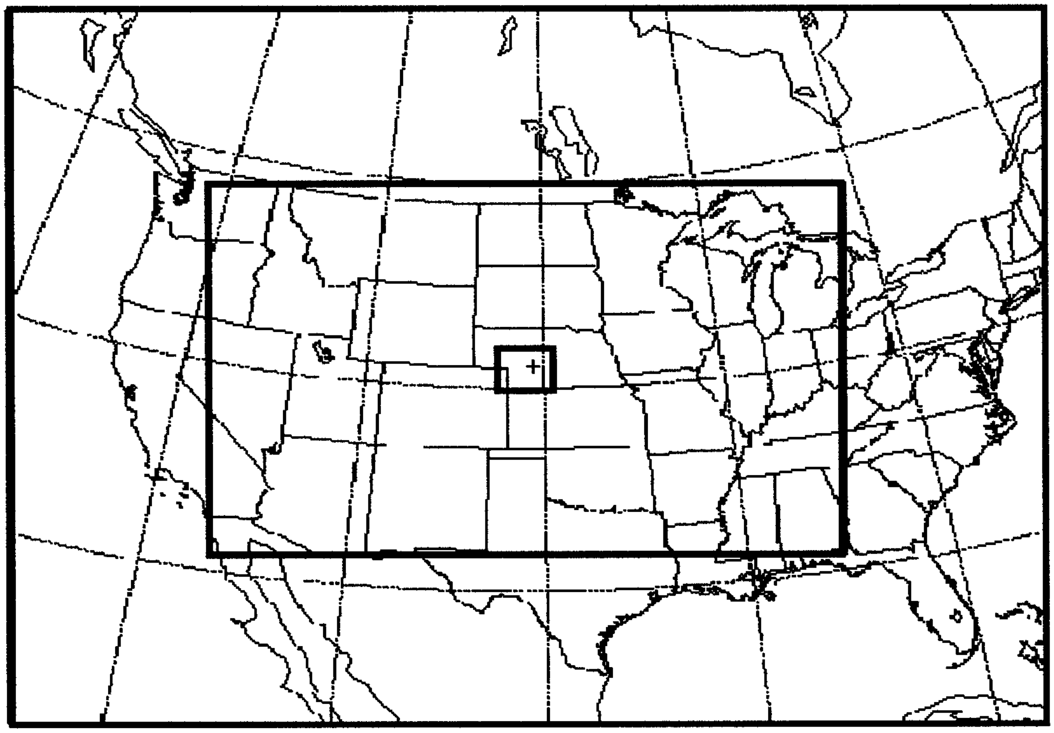


(a)

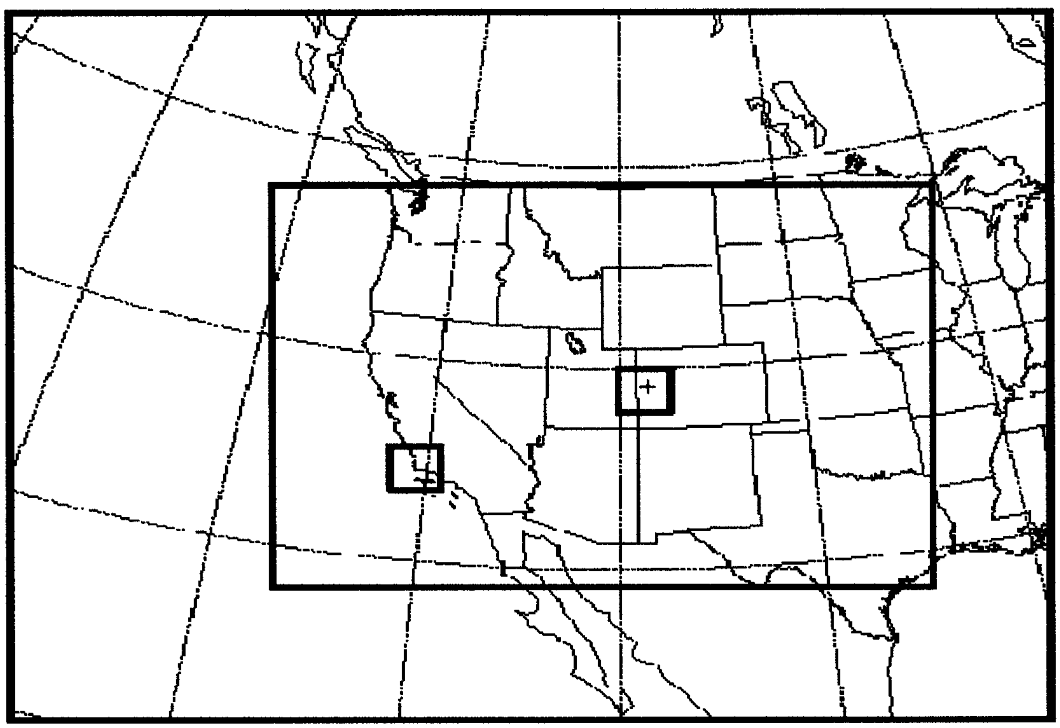


(b)

FIGURE 6: Model Configurations. (a) Configuration centered at Key West. (b) Configuration centered at Lake Charles. Grid 1 is the frame for each picture. Grid 2 is the large box inside the frame, and grid 3 is the small box inside the frame.



(a)



(b)

FIGURE 7: Model Configurations. (a) Configuration centered at North Platte. (b) "West" configuration centered around both Grand Junction and Vandenburg AFB. Grids as in Figure 6.

e. Verification

The four different algorithms' outputs from the simulation (except for the initialization times) were compared to the observed truth from the analysis, and were categorized as before. Chi-square significance testing was also conducted as before. The hand-analyzed forecast PBL estimates from the simulation were also categorized (to use as a comparison tool).

The verification results should not be taken to indicate actual algorithm performance. This research is only designed to test relative algorithm performance. It was assumed that some mistakes were inevitably made in the hand-analysis of the data. However, it was assumed that these errors would not favor one algorithm over another, but would most likely result in all algorithms being put into Category 3. Even if this was not the case, it is highly unlikely that analysis errors would result in a systematic skewing of the data, but would be random. Therefore, the ability to rank algorithm performance is not lost by the introduction of hand-analysis error, but the ability to estimate actual algorithm performance is. In other words, the relative ranking of the algorithms with one another is accurate, but the actual hit rates (as compared to directly sensed PBL heights) may not be.

4. *Analyses and Results*

a. Overview

This chapter presents the analyses and results for the different parts of the research, including two case studies for illustrating the methods employed, and the strengths and weaknesses of the RAMS forecasts made. In the analysis, the observed, hand-analyzed PBL heights are compared with the SLAM algorithms' analyses. In the simulation, the RAMS forecasted, hand-analyzed PBL heights are compared against the TKE method and the SLAM algorithms' estimations. Finally, the verification compares the observed analyses with the four different PBL algorithms, as well as the forecast analyses. Each of the three parts will be broken down by station, each representing a different geophysical regime, followed by a comparison over all regimes. The two case studies will follow. The first case will be for 1200 UTC 7 August 1996, at Key West, Florida. This falls on the 24-hour forecast point for the RAMS model and highlights how well the PIMIX algorithm performs in a convective environment. The second case represents a poor performance by the RAMS model at the 24-hour point. It is for 0000 UTC 17 October 1996, at Grand Junction, Colorado.

b. Analysis

Observations for each of the days in the study were provided by ENSCO, Inc. A PBL height was hand-analyzed for each sounding, as discussed in Chapter 3. Each algorithm computed a PBL height for each observed sounding. The PBL estimates and RMS error categorizations for each algorithm are broken down by station in Appendix D.

1) Key West, Florida

There were 105 soundings for Key West, Florida, which were analyzed. The data were categorized, and chi-square significance testing was performed. The category counts are in Table 2. A 3-way test between the SLAM algorithms is in Table 3. The results from this test support the hypothesis that at least two of the algorithms have a

TABLE 2: Algorithm Performance for Key West, Florida. Category 1 are hits, Category 2 indicate deep convection, Category 3 are misses, and Category 4 are algorithm failures.

Total Counts	PIMIX	POTEMP	RICH
Category 1	64	37	15
Category 2	11	0	0
Category 3	30	67	76
Category 4	0	1	14

TABLE 3: 3-Way Significance Test for Key West, Florida. Categories as in Table 2.

Expected Counts	PIMIX	POTEMP	RICH	Marginal Totals
Category 1	38.67	38.67	38.67	116
Category 2	3.67	3.67	3.67	11
Category 3	57.67	57.67	57.67	173
Category 4	5	5	5	15
Marginal Totals	105	105	105	315

Chi-Square = 98.17 P-Value = 0.000

TABLE 4: 2- Way Significance Test for Key West, Florida. Categories as in Table 2.

Expected Counts	PIMIX	POTEMP	Marginal Totals
Category 1	50.74	50.26	101
Category 2	5.53	5.47	11
Category 3	48.73	48.27	97
Marginal Totals	105	104	209

Chi-Square = 32.33 P-Value = 0.000

significant difference. Since RICH had the fewest hits it was dropped, and a 2-way test was performed on PIMIX and POTEMP, which is in Table 4. Notice Category 4 was dropped from this test because it had expected counts less than one.

The results imply that PIMIX performs better than POTEMP, which is better than RICH. When examining the performance of the different algorithms, PIMIX had far more hits than the other algorithms. In addition, PIMIX was the only algorithm that recorded any Category 2 counts, which is consistent with Kienzle's and Masters' (1990) observation that PIMIX generates higher PBL heights than POTEMP in tropical environments. The fact that PIMIX has more hits than the other algorithms is because it is based on the moist- adiabatic lapse rate. Most of the soundings analyzed for Key West had a nearly moist-adiabatic environmental lapse rate for most of the sounding. It was assumed *a priori* that RICH would be of little use in deeply convective environments, which proved to be true. It rarely recorded a mixing height greater than 1,000 m, and never once indicated deep convection (> 3,000 m). POTEMP also had trouble handling the tropical airmass. It did not appear to have a large enough range of potential temperature gradients to handle this type of airmass. The differences between the three algorithms is most pronounced at this location, suggesting the importance of using PIMIX in tropical environments.

2) Lake Charles, Louisiana

There were 105 soundings analyzed for Lake Charles, Louisiana. The category counts are in Table 5. The data were then subjected to chi-square significance testing, with the 3-way test in Table 6.

TABLE 5: Algorithm Performance for Lake Charles, Louisiana. Categories as in Table 2.

Total Counts	PIMIX	POTEMP	RICH
Category 1	66	55	20
Category 2	9	0	0
Category 3	30	47	68
Category 4	0	3	17

Table 6: 3-Way Significance test for Lake Charles, Louisiana. Categories as in Table 2.

Expected Counts	PIMIX	POTEMP	RICH	Marginal Totals
Category 1	47	47	47	141
Category 2	3	3	3	9
Category 3	48.33	48.33	48.33	145
Category 4	6.67	6.67	6.67	20
Marginal Totals	105	105	105	315
	Chi-Square = 82.25		P-Value = 0.000	

TABLE 7: 2-Way Significance Test for Lake Charles, Louisiana. Categories as in Table 2.

Expected Counts	PIMIX	POTEMP	Marginal Totals
Category 1	60.50	60.50	121
Category 2	4.50	4.50	9
Category 3	38.50	38.50	77
Category 4	1.50	1.50	3
Marginal Totals	105	105	210
	Chi-Square = 19.75	P-Value = 0.001	

The 3-way test suggests there is a significant difference between at least two of the algorithms. RICH was dropped because it had the fewest hits, and a 2-way test was performed between PIMIX and POTEMP, shown in Table 7. The 2-way test also indicates that a significant difference exists between PIMIX and POTEMP.

These results suggest PIMIX performed better than POTEMP, which performed better than RICH. In analyzing the performance of the three SLAM algorithms at this station, it was apparent RICH continued its poor performance, registering only about a third as many hits as the other two algorithms. It also had the highest failure rate. However, POTEMP performed almost as well as PIMIX in this environment. POTEMP still had trouble with the occasional tropical airmass that would settle into the region (especially during the summer months), but showed considerable skill in forecasting the continental air that would settle into the area in the fall and winter months. As before, POTEMP was unable to register any Category 2 counts, indicating its trouble handling deep, moist convection.

3) North Platte, Nebraska

For North Platte, Nebraska, 103 soundings were both hand-analyzed and subjected to the three SLAM algorithms to determine PBL heights. The category counts for the algorithms are in Table 8. The data were then categorized and chi-square significance testing performed. The 3-way test is in Table 9. This test indicated at least two algorithms differed significantly. RICH was dropped because it had fewer hits, and a 2-way test was performed, with the result in Table 10. This time, however, the 2-way test returned a P-Value of 0.771 which indicates that PIMIX and POTEMP do not have significantly different performance. Notice that Category 2 was dropped from the test because it resulted in expected counts less than one.

TABLE 8: Algorithm Performance for North Platte, Nebraska. Categories as in Table 2.

Total Counts	PIMIX	POTEMP	RICH
Category 1	66	63	38
Category 2	1	0	0
Category 3	35	38	52
Category 4	1	2	13

Table 9: 3-Way Significance Test for North Platte, Nebraska. Categories as in Table 2.

Expected Counts	PIMIX	POTEMP	RICH	Marginal Totals
Category 1	55.31	55.85	55.85	167
Category 3	41.40	41.80	41.80	125
Category 4	5.30	5.35	5.35	16
Marginal Totals	102	103	103	308

Chi-Square = 29.03 P-Value = 0.000

TABLE 10: 2-Way Significance Test for North Platte, Nebraska. Categories as in Table 2.

Expected Counts	PIMIX	POTEMP	Marginals
Category 1	64.19	64.81	129
Category 3	36.32	36.68	73
Category 4	1.49	1.51	3
Marginals	102	103	205

Chi-Square = 0.52 P-Value = 0.771

These results show PIMIX and POTEMP perform equally well in this geophysical regime, with no significant difference in hits. However, RICH had about half as many hits as the other two, even in this dry environment. This suggests that it is not very useful. There are several items to note when looking at the performance of the different algorithms. There were only three instances of observed PBL heights greater than 3,000 m AGL, and only one Category 2 count. This is due to the lack of tropical moisture penetrating this far inland and the lack of thunderstorms in the region during any of the observations. Thus, both algorithms were reduced to computing mixing heights based on the dry-adiabatic lapse rate.

4) Vandenburg AFB, California

For Vandenburg AFB, California, there were only 61 times where soundings were available. The majority of the soundings that were missing were from 1200 UTC, so that each day usually had a 0000 UTC sounding, but not a 1200 UTC sounding. There are only two soundings in the dataset from 1200 UTC that show an inversion. The rest of the 1200 UTC had some kind of computable PBL height. The algorithms' output and categorizations are shown in Table 11.

Chi-square significance testing was performed on the data, with the results in Table 12. The resulting P-Value of 0.465 indicates there is no difference in the performance of the algorithms at this station. This is the only station where this occurred.

There are several factors which led to the algorithms having the same performance. Most of the soundings showed very pronounced, low-level subsidence

TABLE 11: Algorithm Performance for Vandenburg AFB, California. Categories as in Table 2.

Total Counts	PIMIX	POTEMP	RICH
Category 1	47	44	39
Category 2	0	0	0
Category 3	13	14	20
Category 4	1	3	2

TABLE 12: 3-Way Significance Test for Vandenburg AFB, California. Categories as in Table 2.

Expected Counts	PIMIX	POTEMP	RICH	Marginal Totals
Category 1	43.33	43.33	43.33	130
Category 3	15.67	15.67	15.67	47
Category 4	2	2	2	6
Marginal Totals	61	61	61	183

Chi-Square = 3.58 P-Value = 0.465

inversions. This helped RICH which generates more low PBL heights than the other algorithms (as seen from the data). The pronounced PBL inversion also helped the other two algorithms. There was only one sounding that had deep convection, and all three algorithms missed it. The remainder were characterized by primarily shallow, dry processes--suggesting PIMIX and POTEMP would have similar performance, as they did at North Platte. The fact that they had similar performance strengthens the argument that their accuracy is the same for dry processes.

5) Grand Junction, Colorado

For Grand Junction, Colorado, 107 soundings were analyzed. The algorithm results and RMS error categorizations are in Table 13. The data were then subjected to chi-square significance testing. The 3-way test is in Table 14, and its result indicates a significant difference between at least two of the algorithms. Since RICH displayed the fewest hits it was dropped, and a 2-way test was conducted (Table 15). This test showed no significant difference existed between the two algorithms.

TABLE 13: Algorithm Performance for Grand Junction, Colorado. Categories as in Table 2.

Total Counts	PIMIX	POTEMP	RICH
Category 1	49	52	35
Category 2	6	6	2
Category 3	52	49	44
Category 4	0	0	26

For this station, there was no significant difference in the number of hits that PIMIX and POTEMP had. RICH had significantly fewer hits for this regime. These results provide more examples of how PIMIX and POTEMP perform the same in a predominately dry environment. The majority of the soundings had dry-adiabatic

TABLE 14: 3-Way Significance Test for Grand Junction, Colorado. Categories as in Table 2.

Expected Counts	PIMIX	POTEMP	RICH	Marginal Totals
Category 1	45.33	45.33	45.33	136
Category 2	4.67	4.67	4.67	14
Category 3	48.33	48.33	48.33	145
Category 4	8.67	8.67	8.67	26
Marginal Totals	107	107	107	321
	Chi-Square = 58.59		P-Value = 0.000	

TABLE 15: 2-Way Significance Test for Grand Junction, Colorado. Categories as in Table 2.

Expected Counts	PIMIX	POTEMP	Marginal Totals
Category 1	50.50	50.50	101
Category 2	6	6	12
Category 3	50.50	50.50	101
Marginal Totals	107	107	214
	Chi-Square = 0.18	P-Value = 0.915	

temperature lapse rates well up into the atmosphere. There are two reasons for this. The first is the nature of the mountainous environment in which the soundings were taken. There is very little moisture available in this area, and the atmosphere tends to mix up to the mountain tops every afternoon, especially during the summer. The second is the way the soundings are collected. Because the ground is above 850 hPa, the Rawinsonde will record data for the surface and will not record any more until 700 hPa if it does not detect a significant level in between. This helps to smooth slight (but perhaps significant) inversions in the data. I suspect that some soundings were overly smoothed, but I could not clearly determine the presence of such a phenomenon. Regardless, the resulting soundings tended to be very smooth and dry--displaying the classic inverted vee characteristic of the PBL described in Chapter 2. Again, PIMIX and POTEMP were seen to have similar performance in this type of environment. RICH performed better here than at some other locations, but did not have as many hits as PIMIX and POTEMP because the bulk of the inversions were fairly high, and, as noted before, RICH seems to have a bias towards low PBL estimates.

6) Total Observed Algorithm Performance

The analysis category counts for each algorithm were summed for all stations and are shown in Table 16. Chi-Square significance testing was performed, with the 3-way test in Table 17. This test indicated a significant difference between two of the algorithms, so a 2-way test was performed after dropping the RICH algorithm. Its result is in Table 18 and shows that a significant difference exists between PIMIX and POTEMP.

TABLE 16: Overall Analysis Algorithm Performance. Categories as in Table 2.

Total Counts	PIMIX	POTEMP	RICH
Category 1	292	251	147
Category 2	27	6	2
Category 3	160	215	260
Category 4	2	9	72

These results indicate PIMIX has the highest number of hits of any of the three SLAM algorithms. This is because PIMIX was equal to or better than the other algorithms at every station. Furthermore, RICH had the fewest number of hits. PIMIX is the only algorithm that handles moist environments well, and can adequately deal with

TABLE 17: Overall Analysis 3-Way Significance Test. Categories as in Table 2.

Expected Counts	PIMIX	POTEMP	RICH	Marginal Totals
Category 1	230	230	230	690
Category 2	11.67	11.67	11.67	35
Category 3	211.67	211.67	211.67	635
Category 4	27.67	27.67	27.67	83
Marginal Totals	481	481	481	1443

Chi-Square = 210.64 P-Value = 0.000

TABLE 18: Overall Analysis 2-Way Significance Test. Categories as in Table 2.

Expected Counts	PIMIX	POTEMP	Marginal Totals
Category 1	271.50	271.50	543
Category 2	16.50	16.50	33
Category 3	187.50	187.50	375
Category 4	5.50	5.50	11
Marginal Totals	481	481	962

Chi-Square = 28.98 P-Value = 0.000

dry environments. POTEMP is equal to PIMIX in dry environments, but cannot deal with moist environments. PIMIX appears to be the most consistent across all tested geophysical regimes.

c. Simulation

Sounding forecasts were made using RAMS for each of the stations as specified in Chapter 3. PBL heights were determined, and the soundings were analyzed by the three SLAM algorithms and the TKE post-processing routine. The results of the analyses are in Appendix E. The statistical analysis of the data follows.

1) Key West, Florida

For Key West, Florida, there were 107 soundings generated by RAMS for 36 different days. The category counts for the different algorithms are in Table 19. Chi-square significance testing was performed on the categorized data, with the 4-way test results in Table 20. Category 4 was excluded from significance testing because its expected counts were zero. The 4-way results indicated that at least two of the algorithms had a significant difference in their performance. Since RICH had the largest apparent difference, it was removed from consideration, and 3-way testing was done on the remaining algorithms, with the results in Table 21. Again, these results showed that at least two of the algorithms had significant differences. The PIMIX algorithm was

TABLE 19: Algorithm Performance for Key West, Florida. Category 1 are hits, Category 2 indicate deep convection, Category 3 are misses, and Category 4 are algorithm failures.

Total Counts	PIMIX	POTEMP	RICH	TKE
Category 1	14	23	7	17
Category 2	29	0	0	0
Category 3	64	84	100	55
Category 4	0	0	0	0

Table 20: 4-Way Significance Test for Key West, Florida. Categories as in Table 19.

Expected Counts	PIMIX	POTEMP	RICH	TKE	Marginals
Category 1	16.61	16.61	16.61	11.18	61
Category 2	7.90	7.90	7.90	5.31	29
Category 3	82.50	82.50	82.50	55.51	303
Marginals	107	107	107	72	393

Chi-Square = 96.87 P-Value = 0.000

TABLE 21: 3-Way Significance Test for Key West, Florida. Categories as in Table 19.

Expected Counts	PIMIX	POTEMP	TKE	Marginals
Category 1	20.20	20.20	13.59	54
Category 2	10.85	10.85	7.30	29
Category 3	75.95	75.95	51.10	203
Marginals	107	107	72	286

Chi-Square = 54.69 P-Value = 0.000

removed from consideration since it accounted for the bulk of the difference, and 2-way testing was performed in Table 22. The result of the 2-way test indicates there is no significant difference between the POTEMP and TKE algorithms.

These results show that POTEMP and TKE have similar hit rates, and RICH has the fewest number of hits. PIMIX had more hits than RICH, but was not as accurate as POTEMP or TKE; however, it did much better analyzing convective environments with

TABLE 22: 2-Way Significance Test for Key West, Florida. Categories as in Table 19.

Expected Counts	POTEMP	TKE	Marginals
Category 1	23.91	16.09	40
Category 3	83.09	55.91	139
Marginals	107	72	179

Chi-Square = 0.11 P-Value = 0.739

29 estimates that indicated deep convection. PIMIX appears to have been too sensitive to moisture. It often overestimated the PBL height, which is why it had so few hits. PIMIX did not perform as well as POTEMP or TKE, because accuracy is more important than indicating the presence of deep moisture. Note that PIMIX was not very accurate in this forecast environment when this was its best regime in the analysis.

2) Lake Charles, Louisiana

For Lake Charles, Louisiana, there were 108 soundings generated from 36 days. The algorithm category counts are shown in Table 23. Chi-square significance testing was performed on the categorized data, with the 4-way test in Table 24. Category 4 had to be dropped from the testing because it contained expected counts less than one. The result of the 4-way test suggests that at least two of the algorithms differ. RICH was dropped because it had the fewest hits, and 3-way testing was performed. The results are in Table 25. The 3-way test result suggests that at least two of the algorithms differ. PIMIX is the most different, so it is dropped from further testing, and a 2-way significance test is performed in Table 26. With a P-Value of 0.714, this test leads to the acceptance of the null hypothesis that there is no significant difference between POTEMP and TKE.

TABLE 23: Algorithm Performance for Lake Charles, Louisiana. Categories as in Table 19.

Total Counts	PIMIX	POTEMP	RICH	TKE
Category 1	36	48	26	34
Category 2	10	0	0	0
Category 3	62	60	80	38
Category 4	0	0	2	0

The results of the various tests indicate that POTEMP and TKE perform equally well and have significantly more hits than the other algorithms. RICH has the fewest number of hits, while PIMIX showed the same tendency to overestimate the PBL heights in the presence of moisture as was noted at Key West. Again, it is interesting to note that the algorithm that had the most hits in the analysis, has poorer performance in the simulation.

Table 24: 4-Way Significance Test for Lake Charles, Louisiana. Categories as in Table 19.

Expected Counts	PIMIX	POTEMP	RICH	TKE	Marginals
Category 1	39.47	39.47	38.74	26.31	144
Category 2	2.74	2.74	2.69	1.83	10
Category 3	65.79	65.79	64.57	43.86	240
Marginals	108	108	106	72	394
	Chi-Square = 40.26		P-Value = 0.000		

TABLE 25: 3-Way Significance Test for Lake Charles, Louisiana. Categories as in Table 19.

Expected Counts	PIMIX	POTEMP	TKE	Marginals
Category 1	44.25	44.25	29.50	118
Category 2	3.75	3.75	2.50	10
Category 3	60	60	40	160
Marginals	108	108	72	288
	Chi-Square = 19.38		P-Value = 0.001	

TABLE 26: 2-Way Significance Test for Lake Charles, Louisiana. Categories as in Table 19.

Expected Counts	POTEMP	TKE	Marginals
Category 1	49.20	32.80	82
Category 3	58.80	39.20	98
Marginals	108	72	180
	Chi-Square = 0.13	P-Value = 0.714	

3) North Platte, Nebraska

For North Platte, Nebraska, there were 102 soundings that were analyzed for 34 days. The category counts for the algorithms' outputs are in Table 27. Chi-square significance testing was done, with the 4-way test in Table 28, and the 3-way test in

Table 29. Categories 2 and 4 had to be dropped from testing because they had expected values less than one.

The result of the 4-way test was inconclusive. Since RICH appeared to have the poorest performance, it was removed, and 3-way testing was conducted. The result of the 3-way test indicates no significant difference exists in the accuracy of PIMIX, POTEMP,

TABLE 27: Algorithm Performance for North Platte, Nebraska. Categories as in Table 19.

Total Counts	PIMIX	POTEMP	RICH	TKE
Category 1	44	53	32	35
Category 2	3	0	0	0
Category 3	55	49	69	33
Category 4	0	0	1	0

TABLE 28: 4-Way Significance Test for North Platte, Nebraska. Categories as in Table 19.

Expected Counts	PIMIX	POTEMP	RICH	TKE	Marginals
Category 1	43.88	45.21	44.77	30.14	164
Category 3	55.12	56.79	56.23	37.86	206
Marginals	99	102	101	68	370

Chi-Square = 10.36 P-Value = 0.016

TABLE 29: 3-Way Significance Test for North Platte, Nebraska. Categories as in Table 19.

Expected Counts	PIMIX	POTEMP	TKE	Marginals
Category 1	48.58	50.05	33.37	132
Category 3	50.42	51.95	34.63	137
Marginals	99	102	68	269

Chi-Square = 1.35 P-Value = 0.510

and TKE. RICH has similar performance, but possibly poorer. As was seen in the observed cases, the differences in the algorithms tend to disappear in an environment dominated by dry processes.

4) Vandenburg AFB, California

For Vandenburg AFB, California, there were 105 soundings from 35 days. The algorithm category counts are in Table 30. Chi-square significance testing was performed, with the 4-way test in Table 31. Categories 2 and 4 were dropped because they had expected counts less than one. This test indicated there was a significant difference between at least two of the algorithms. Since RICH appeared to have the fewest hits, it was dropped from testing, and a 3-way test was conducted in Table 32, which indicated no significant difference.

TABLE 30: Algorithm Performance for Vandenburg AFB, California. Categories as in Table 19.

Total Counts	PIMIX	POTEMP	RICH	TKE
Category 1	57	70	34	39
Category 2	1	0	0	0
Category 3	47	34	71	31
Category 4	0	1	0	0

TABLE 31: 4-Way Significance Test for Vandenburg AFB, California. Categories as in Table 19.

Expected Counts	PIMIX	POTEMP	RICH	TKE	Marginals
Category 1	54.31	54.31	54.83	36.55	200
Category 3	49.69	49.69	50.17	33.45	183
Marginals	104	104	105	70	383
		Chi-Square = 26.67		P-Value = 0.000	

PIMIX, POTEMP and TKE had the same accuracy at this station, while RICH had the fewest hits. The fact that RICH did not work well for these forecasted cases suggests that it does not work well on any forecasted soundings.

TABLE 32: 3-Way Significance Test for Vandenburg AFB, California. Categories as in Table 19.

Expected Counts	PIMIX	POTEMP	TKE	Marginals
Category 1	62.10	62.10	41.80	166
Category 3	41.90	41.90	28.20	112
Marginals	104	104	70	278
	Chi-Square = 4.00		P-Value = 0.135	

5) Grand Junction, Colorado

For Grand Junction, Colorado, there were 105 soundings generated over 35 days. The algorithms' output category counts are in Table 33. Chi-square significance testing was done, with the 4-way test in Table 34. This test indicated that at least two of the algorithms differed, so a 3-way test was performed in Table 35. PIMIX appeared to be the most different, so it was dropped. Again, a difference between at least two of the algorithms was indicated, so a 2-way test was performed, after dropping RICH (Table 36). This test suggests there is no significant difference between POTEMP and TKE.

TABLE 33: Algorithm Performance for Grand Junction, Colorado. Categories as in Table 19.

Total Counts	PIMIX	POTEMP	RICH	TKE
Category 1	20	36	33	30
Category 2	11	5	0	0
Category 3	74	64	66	40
Category 4	0	0	6	0

POTEMP and TKE perform equally well and better than the other algorithms. Again, PIMIX does better indicating the presence of deep convection, but tends to overestimate PBL heights because of its sensitivity to moisture, thus rendering it far less accurate than POTEMP and TKE. RICH had the poorest performance, as indicated by the number of misses and algorithm failures.

TABLE 34: 4-Way Significance Test for Grand Junction, Colorado. Categories as in Table 19.

Expected Counts	PIMIX	POTEMP	RICH	TKE	Marginals
Category 1	32.45	32.45	32.45	21.64	119
Category 2	4.36	4.36	4.36	2.91	16
Category 3	66.55	66.55	66.55	44.36	244
Category 4	1.64	1.64	1.64	1.09	6
Marginals	105	105	105	70	385
		Chi-Square = 43.23		P-Value = 0.000	

TABLE 35: 3-Way Significance Test for Grand Junction, Colorado. Categories as in Table 19.

Expected Counts	POTEMP	RICH	TKE	Marginals
Category 1	37.13	37.13	24.75	99
Category 2	1.88	1.88	1.25	5
Category 3	63.75	63.75	42.50	170
Category 4	2.25	2.25	1.50	6
Marginals	105	105	70	280
	Chi-Square = 20.17		P-Value = 0.002	

TABLE 36: 2-Way Significance Test for Grand Junction, Colorado. Categories as in Table 19.

Expected Counts	POTEMP	TKE	Marginals
Category 1	39.60	26.40	66
Category 3	62.40	41.60	104
Marginals	105	70	175
Chi-Square = 4.25		P-Value = 0.119	

6) Total Forecasted Algorithm Performance

The total category counts over all cases were tested to determine which algorithm has the best overall performance. The overall category counts are in Table 37. The 4-way chi-square significance test is in Table 38. The 4-way test shows a significant difference exists between at least two of the algorithms. Since RICH has the fewest hits,

TABLE 37: Overall Simulation Algorithm Performance. Categories as in Table 19.

Total Counts	PIMIX	POTEMP	RICH	TKE
Category 1	171	230	132	155
Category 2	54	5	0	0
Category 3	302	291	386	197
Category 4	0	1	9	0

TABLE 38: Overall Simulation 4-Way Significance Test. Categories as in Table 19.

Expected Counts	PIMIX	POTEMP	Rich	TKE	Marginals
Category 1	187.57	187.57	187.57	125.29	688
Category 2	16.09	16.09	16.09	10.74	59
Category 3	320.62	320.62	320.62	214.15	1176
Category 4	2.73	2.73	2.73	2.73	10
Marginals	527	527	527	352	1933

Chi-Square = 197.01 P-Value = 0.000

TABLE 39: Overall Simulation 3-Way Significance Test. Categories as in Table 19.

Expected Counts	PIMIX	POTEMP	TKE	Marginals
Category 1	208.55	208.15	139.30	556
Category 2	22.13	22.09	14.78	59
Category 3	296.32	295.76	197.92	790
Marginals	527	526	352	1405

Chi-Square = 84.91 P-Value = 0.002

TABLE 40: Overall Simulation 2-Way Significance Test. Categories as in Table 19.

Expected Counts	POTEMP	TKE	Marginals
Category 1	230.65	154.35	385
Category 2	3	2	5
Category 3	292.36	195.64	488
Marginals	526	352	878
	Chi-Square = 3.37	P-Value = 0.186	

it is dropped, and 3-way testing performed, in Table 39. This indicates at least two of the algorithms differ, so PIMIX is dropped because it appears the most different. A 2-way test is then performed in Table 40, which suggests no significant difference exists between the POTEMP and TKE.

POTEMP and TKE perform the same and better than the other two algorithms. PIMIX indicates the presence of deep, moist convection better than any other algorithm, but at the expense of accuracy. RICH had the least hits overall, and accounted for all but one of the algorithm failures recorded.

Why did PIMIX not perform as well on forecasted soundings as it did on observed soundings? There are a couple of possibilities. One, there were systemic errors in the forecasted PBL analyses. If RAMS were actually generating convective showers more often than analyzed, this could skew the category results towards POTEMP and TKE, which do not take moist processes into account. The other possibility is RAMS smoothes the vertical profile of temperature and moisture just enough to allow the PIMIX algorithm to overlook significant changes in lapse rate. PIMIX was designed to filter out some of the inherent noise of real soundings. This noise is absent in RAMS generated soundings, but in its place is slight vertical smoothing. Both of these may be to blame for PIMIX's poor performance.

d. Verification

Each of the forecasted PBL estimates made, both hand-analyzed and algorithm-generated, were compared to the observed truth. The data were then categorized, as discussed in Chapter 3. The results, broken down by station, are in Appendix F. The statistical analysis follows.

1) Key West, Florida

Of the 71 hand-analyzed forecasted PBL heights for Key West, Florida, 23 were hits, 31 were misses, and 17 indicated deep convection, for a hit rate of 33%. The algorithm category counts are in Table 41. Chi-square significance testing was preformed on the algorithms to determine which verified best. The 4-way test is in Table 42. It indicates a significant difference exists between at least two of the algorithms. Since PIMIX is the most different, it is dropped, and a 3-way test is conducted in Table 43. This test indicates no significant difference exists between the algorithms. To determine if the difference in hits between PIMIX and POTEMP was significant, Category 2 counts were dropped, and a 2-way significance test was conducted (Table 44). This indicated no significant difference between the two algorithms.

The data suggest PIMIX was the best performer. It had the same accuracy as POTEMP, but indicated deep convection better. The other three algorithms performed roughly the same. The fact that PIMIX verifies better than it performed within the

TABLE 41: Algorithm Performance for Key West, Florida. Category 1 are hits, Category 2 indicate deep convection, Category 3 are misses, and Category 4 are algorithm failures.

Total Counts	PIMIX	POTEMP	RICH	TKE
Category 1	10	14	8	8
Category 2	25	0	0	0
Category 3	36	57	63	63
Category 4	0	0	0	0

TABLE 42: 4-Way Significance Test for Key West, Florida. Categories as in Table 41.

Expected Counts	PIMIX	POTEMP	RICH	TKE	Marginals
Category 1	10	10	10	10	40
Category 2	6.25	6.25	6.25	6.25	25
Category 3	54.75	54.75	54.75	54.75	219
Marginals	71	71	71	71	284

Chi-Square = 86.40 P-Value = 0.000

TABLE 43: 3-Way Significance Test for Key West, Florida. Categories as in Table 41.

Expected Counts	POTEMP	RICH	TKE	Marginals
Category 1	10	10	10	30
Category 3	61	61	61	183
Marginals	71	71	71	213

Chi-Square = 2.79 P-Value = 0.247

modeling environment suggests that there may have been a systemic error in the method used to analyze the forecasted soundings. However, the forecasted hand-analyses verified better than any of the algorithms, suggesting there was not a significant problem with the analyses. That PIMIX had slightly fewer hits than POTEMP may be due to the previously mentioned problems that PIMIX may have with the smoothed, forecasted soundings.

TABLE 44: Modified 2-Way Significance Test between PIMIX and POTEMP at Key West, Florida. Categories as in Table 41.

Expected Counts	PIMIX	POTEMP	Marginals
Category 1	9.44	14.56	24
Category 3	36.56	56.44	93
Marginals	105	105	210
	Chi-Square = 0.07	P-Value = 0.792	

2) Lake Charles, Louisiana

There were 70 verified soundings for Lake Charles, Louisiana. For the hand-analyzed soundings, 22 were hits, 43 were misses, and 5 indicated deep convection, yielding a 31% hit rate. The algorithm category counts are in Table 45. Significance testing was performed on the outputs of the algorithms to determine which was best. The 4-way test is in Table 46. It indicates that at least two of the algorithms differ. PIMIX was the most different, so it was dropped, and a 3-way test was performed in Table 47. This test indicated no significant difference between the remaining three algorithms.

TABLE 45: Algorithm Performance for Lake Charles, Louisiana. Categories as in Table 41.

Total Counts	PIMIX	POTEMP	Rich	TKE
Category 1	19	14	12	15
Category 2	7	0	0	0
Category 3	44	56	56	55
Category 4	0	0	2	0

These results indicate that PIMIX had the most hits and indicated deep convection better than the other algorithms. The rest of the algorithms had similar hit rates among themselves. Again, PIMIX verified better than it performed in simulation. What is somewhat surprising is that RICH verified equally with POTEMP and TKE. This may result because most of the hits all three of these algorithms had were for relatively low PBL heights. As observed PBL heights increased, all algorithms' performance dropped.

TABLE 46: 4-Way Significance Test for Lake Charles, Louisiana. Categories as in Table 41.

Expected Counts	PIMIX	POTEMP	RICH	TKE	Marginals
Category 1	15.11	15.11	14.68	15.11	60
Category 2	1.76	1.76	1.71	1.76	7
Category 3	53.13	53.13	51.61	53.13	211
Marginals	70	70	68	70	278
	Chi-Square = 24.54		P-Value = 0.000		

TABLE 47: 3-Way Significance Test for Lake Charles, Louisiana. Categories as in Table 41.

Expected Counts	POTEMP	RICH	TKE	Marginals
Category 1	13.80	13.40	13.80	41
Category 3	56.20	54.60	56.20	167
Marginals	70	68	70	208
	Chi-Square = 0.32		P-Value = 0.853	

3) North Platte, Nebraska

There were 67 soundings that were verified for North Platte, Nebraska. For the hand-analyzed "forecasted truth," 27 were hits, 39 were misses, and one indicated deep convection. This resulted in a 40% hit rate. The algorithm category counts are in Table 48. Significance testing on the algorithms was conducted in Table 49 to determine which verified best. The results suggest no significant difference exists between the four algorithms. Categories 2 and 4 were dropped from testing because of expected counts less than one.

TABLE 48: Algorithm Performance for North Platte, Nebraska. Categories as in Table 41.

Total Counts	PIMIX	POTEMP	RICH	TKE
Category 1	23	24	20	25
Category 2	1	0	0	0
Category 3	43	43	46	42
Category 4	0	0	1	0

TABLE 49: 4-Way Significance Test for North Platte, Nebraska. Categories as in Table 41.

Expected Counts	PIMIX	POTEMP	RICH	TKE	Marginals
Category 1	22.83	23.17	22.83	23.17	92
Category 3	43.17	43.83	43.17	43.83	174
Marginals	66	67	66	67	266

Chi-Square = 0.80 P-Value = 0.849

These results indicate no significant difference in the performance of the different algorithms at this site. This is consistent with what was found in simulation, except RICH performed better this time. As was noticed in the analysis cases, the performance of the algorithms tend to become similar in the presence of dry processes. This trend seems to continue for verification as well.

4) Vandenburg AFB, California

Only 40 cases were verified at Vandenburg AFB, California, because of the gaps in the observed data. For the hand-analyzed analysis, 15 were hits, 24 were misses, and one indicated deep convection. The resulting hit rate was 38%. The algorithm category counts are in Table 50. The algorithms' performances were determined through chi-square significance testing. The 4-way test is in Table 51. The results of the 4-way test show no significant difference exists between the algorithms' performance. This is consistent with the results of the analysis—the algorithms tend to have similar performance in this environmental regime.

TABLE 50: Algorithm Performance for Vandenburg AFB, California. Categories as in Table 41.

Total Counts	PIMIX	POTEMP	RICH	TKE
Category 1	7	9	14	6
Category 2	0	0	0	0
Category 3	33	31	26	34
Category 4	0	0	0	0

TABLE 51: 4-Way Significance Test for Vandenburg AFB, California. Categories as in Table 41.

Expected Counts	PIMIX	POTEMP	RICH	TKE	Marginals
Category 1	9	9	9	9	36
Category 3	31	31	31	31	124
Marginals	40	40	40	40	160
		Chi-Square = 5.45		P-Value = 0.142	

5) Grand Junction, Colorado

There were 69 cases verified for Grand Junction, Colorado. For the hand-analyzed "forecasted truth," there were 21 hits, 45 misses, and three that indicated deep convection, resulting in a 30% hit rate. The algorithm category counts are in Table 52. The performances of the algorithms against each other were determined through chi-square significance testing. The 4-way test is in Table 53. This test indicated a significant difference existed between at least two of the algorithms. Since RICH was the most different, it was dropped and 3-way testing performed in Table 54. The result of this test was inconclusive. TKE was dropped because it was the most different. The 2-way test in Table 55 indicated no significant difference between PIMIX and POTEMP.

TABLE 52: Algorithm Performance for Grand Junction, Colorado. Categories as in Table 41.

Total Counts	PIMIX	POTEMP	RICH	TKE
Category 1	15	13	20	28
Category 2	11	8	0	4
Category 3	43	48	46	37
Category 4	0	0	3	0

TABLE 53: 4-Way Significance Test for Grand Junction, Colorado. Categories as in Table 41.

Expected Counts	PIMIX	POTEMP	RICH	TKE	Marginals
Category 1	19.21	19.21	18.37	19.21	76
Category 2	5.81	5.81	5.56	5.81	23
Category 3	43.98	43.98	42.07	43.98	174
Marginals	69	69	66	69	273

Chi-Square = 20.54 P-Value = 0.002

TABLE 54: 3-Way Significance Test for Grand Junction, Colorado. Categories as in Table 41.

Expected Counts	PIMIX	POTEMP	TKE	Marginals
Category 1	18.67	18.67	18.67	56
Category 2	7.67	7.67	7.67	23
Category 3	42.67	42.67	42.67	128
Marginals	69	69	69	207

Chi-Square = 11.75 P-Value = 0.019

TABLE 55: 2-Way Significance Test for Grand Junction, Colorado. Categories as in Table 41.

Expected Counts	PIMIX	POTEMP	Marginals
Category 1	14	14	28
Category 2	11	8	19
Category 3	45.50	45.50	91
Marginals	69	69	138

Chi-Square = 0.89 P-Value = 0.640

These results suggest that all four algorithms had similar accuracy, but PIMIX, POTEMP, and TKE indicated deep convection equally well and better than RICH. However, TKE may indicate deep convection better than the other algorithms. This was a very difficult regime to analyze because of the elevation of the station, as mentioned in the analysis. The forecast soundings did not have this problem, however. With the extra resolution in the low levels (as compared to the observations), low level features that were suspected in the observations, but could not be resolved by them, became apparent. The algorithms analyzed these low level forecast features that were missed in the observations. This resulted in fewer hits for all the algorithms.

6) Total Verified Algorithm Performance

For the hand-analyzed soundings, there were 108 hits, 182 misses, and 27 that indicated deep convection, for a hit rate of 34%. The overall algorithm category counts are in Table 56. Chi-square significance testing was conducted on the overall performance of the algorithms. The 4-way test is in Table 57. The result of this test indicates that at least two of the algorithms differ. The greatest variations were because of the Category 2 and 4 counts. Therefore, Categories 2 and 4 were dropped, and significance testing was conducted on just the hit counts (Table 58). This test showed no difference in the hit counts for all four of the algorithms. To double check, POTEMP and

TABLE 56: Overall Verification Algorithm Performance. Categories as in Table 41.

Total Counts	PIMIX	POTEMP	RICH	TKE
Category 1	74	74	74	82
Category 2	44	8	0	4
Category 3	199	235	237	231
Category 4	0	0	6	0

TKE were compared in Table 59. Since POTEMP had the same number of hits as PIMIX, if POTEMP and TKE tested the same, this would show PIMIX was superior because of its Category 2 performance. This was the case.

Table 57: Overall Verification 4-Way Significance Test. Categories as in Table 41.

Expected Counts	PIMIX	POTEMP	RICH	TKE	Marginals
Category 1	76	76	76	76	304
Category 2	14	14	14	14	56
Category 3	225.50	225.50	225.50	225.50	902
Category 4	1.50	1.50	1.50	1.50	6
Marginals	317	317	317	317	1268

Chi-Square = 110.87 P-Value = 0.000

TABLE 58: Modified Overall Verification 4-Way Significance Test. Categories as in Table 41.

Expected Counts	PIMIX	POTEMP	RICH	TKE	Marginals
Category 1	68.82	77.89	78.39	78.90	304
Category 3	204.18	231.11	232.61	234.10	902
Marginals	273	309	311	313	1206

Chi-Square = 1.27 P-Value = 0.735

TABLE 59: Overall Verification 2-Way Significance Test. Categories as in Table 41.

Expected Counts	POTEMP	TKE	Marginals
Category 1	78	78	156
Category 2	6	6	12
Category 3	233	233	466
Marginals	317	317	634

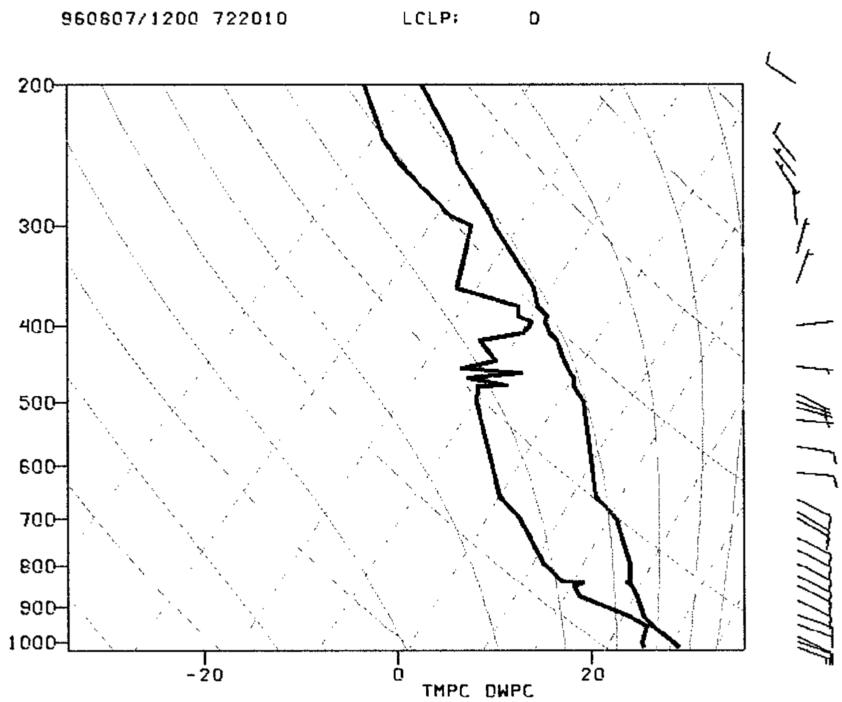
Chi-Square = 1.78 P-Value = 0.411

These results indicate PIMIX verified the best, but not because it had greater accuracy than the other algorithms. POTEMP and TKE had the same hit rate as PIMIX, but indicated deep convection less. RICH had the poorest performance, but only because of the number of algorithm failures. If Category 4 were dropped, its performance was as good as POTEMP and TKE (test conducted, but not shown).

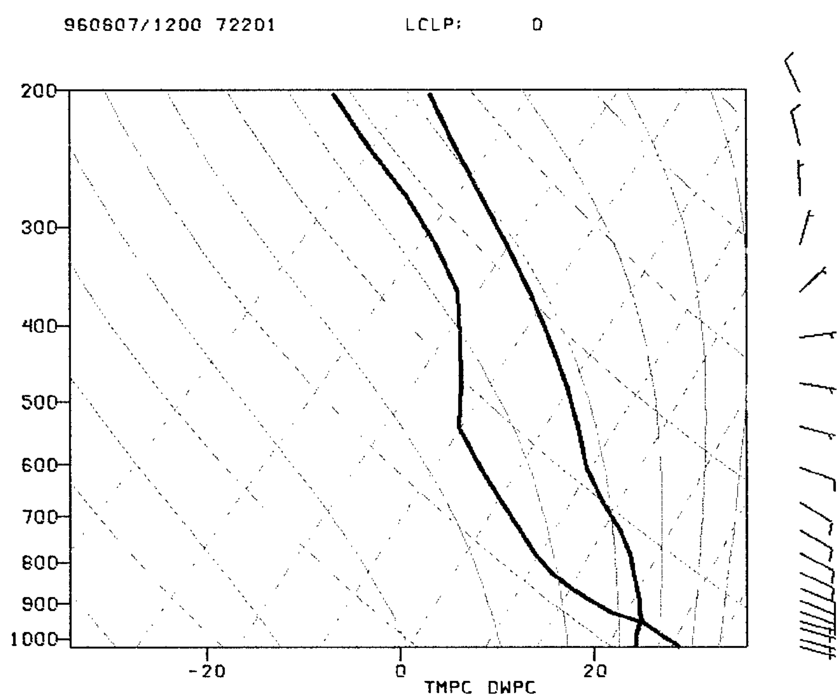
These results are somewhat similar to the results from the analysis; however, PIMIX did not perform better in hit rate, as it did in the analysis. The other three algorithms appear to be solid methods for analyzing dry environments, but have little ability to add information in moist environments as can PIMIX (by indicating deep convection). RICH tends to have more algorithm failures than the other methods.

e. Case Study I. 1200 UTC 7 August 1996, at Key West, Florida

This 1200 UTC 7 August 1996 case falls on the RAMS 24-hour forecast and represents one where the model sounding compared very well with the observation. Thunderstorms were frequent the previous day, and several observations were taken in the region that showed thunderstorms, rain, and precipitation amounts (Appendix B). The observed 1200 UTC 7 August 1996 sounding for EYW still showed the presence of deep, moist convection in the region. This compares quite well with the forecasted sounding for the same period (Figure 8). Analysis of the 500 hPa height field showed that the model had resolved the pattern well, although there was a slight bias towards higher values by the 24-hour forecast point (Figure 9). The forecasted 500 hPa relative humidity (RH) field was smooth while the observations were quite chaotic, indicative of convection (Figure 10). This made it impossible to compare the two. The surface pressure field was very uniform, and no significant differences were noted between the 24-hour forecast and the observations (not shown). However, a very curious trend was noticed on the forecasted surface RH fields (Figures 11 and 12) even though the analyzed

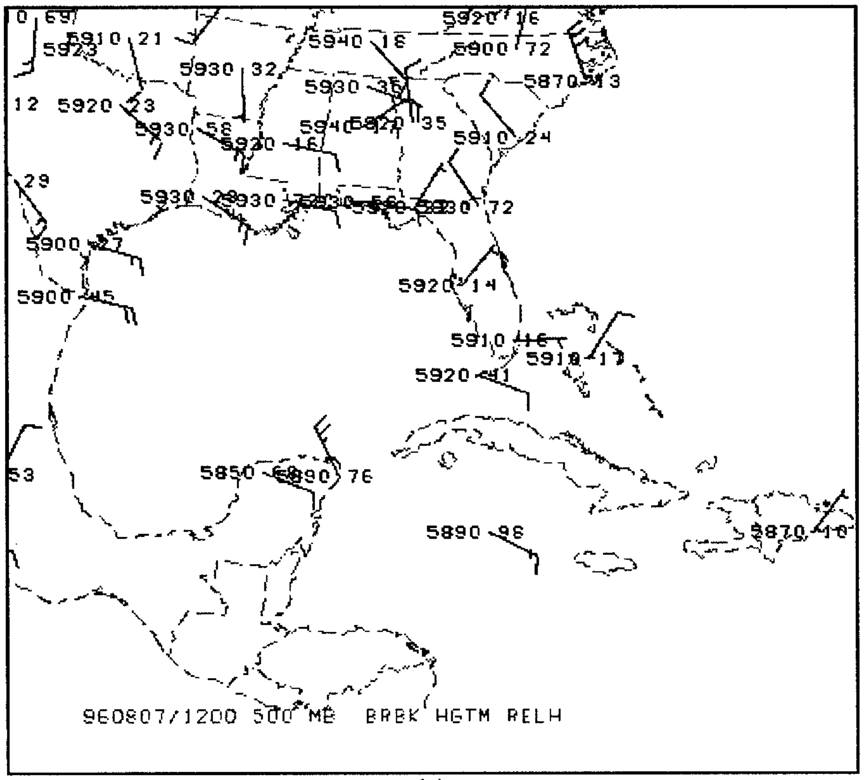


(a)

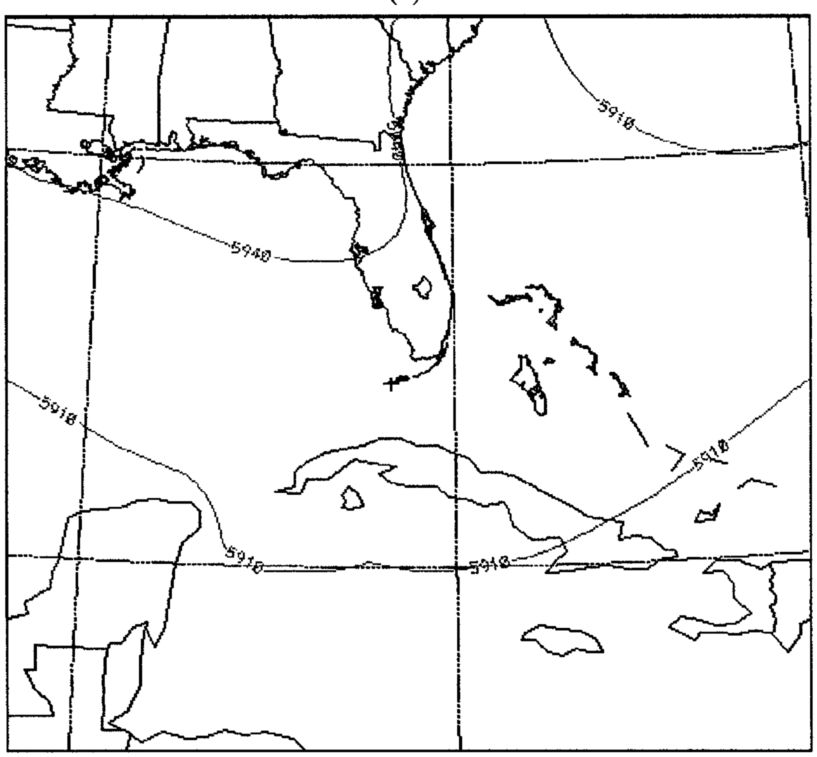


(b)

FIGURE 8: 1200 UTC 7 August 1996, Skew-*T*s at EYW. (a) Observed. (b) Forecasted.



(a)



(b)

FIGURE 9: 1200 UTC 7August 1996, 500 hPa. (a) Observed geopotential heights (m) and RH. (b) Forecasted geopotential heights (m).

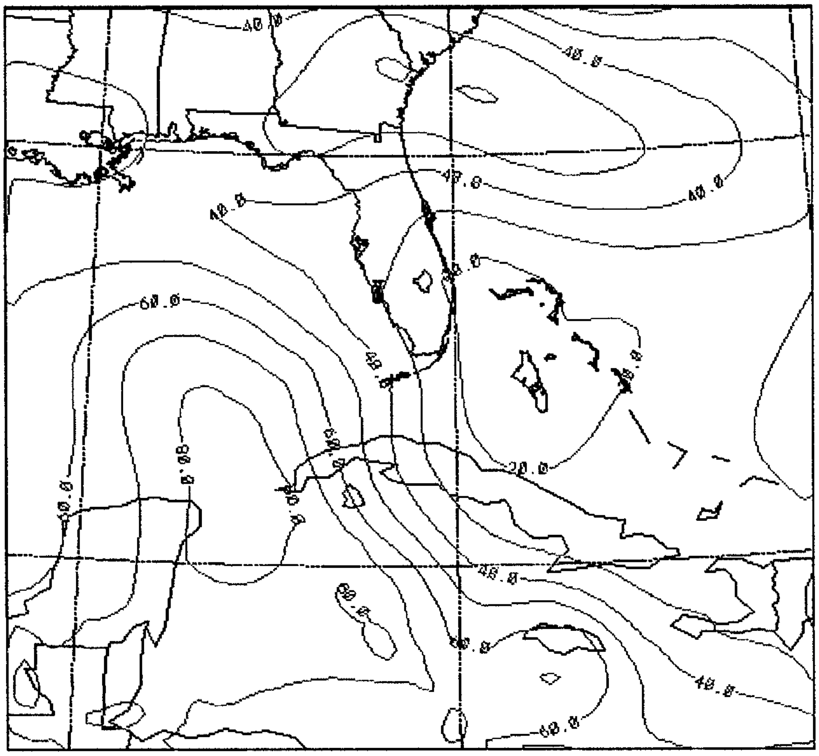


FIGURE 10: 1200 UTC 7 August 1996, 500 hPa Forecast Geopotential Heights. Compare with Figure 9(a).

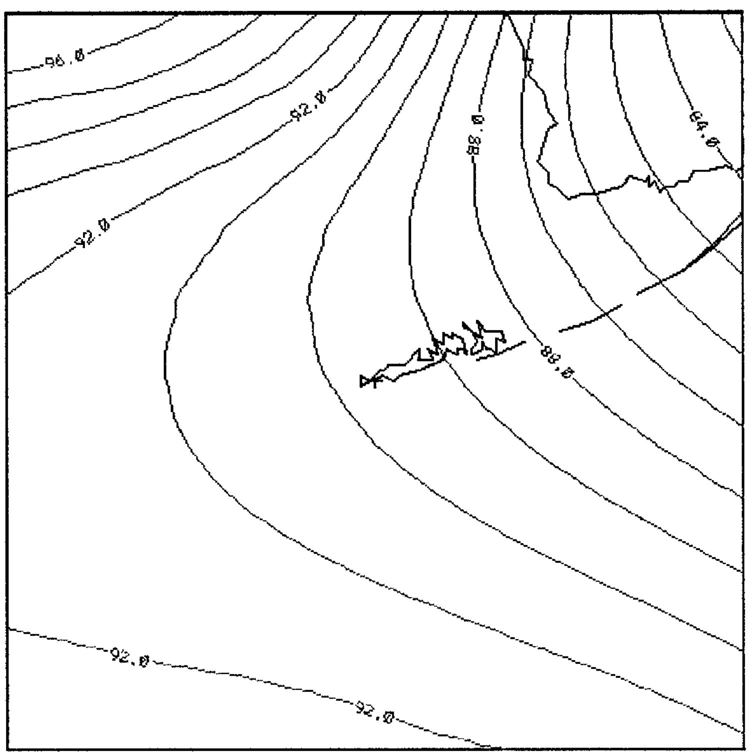
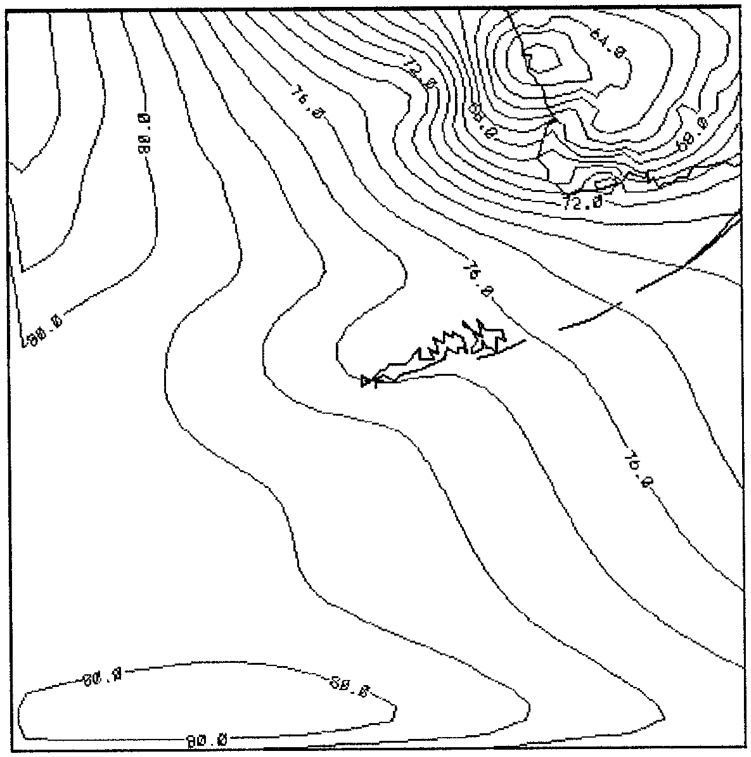
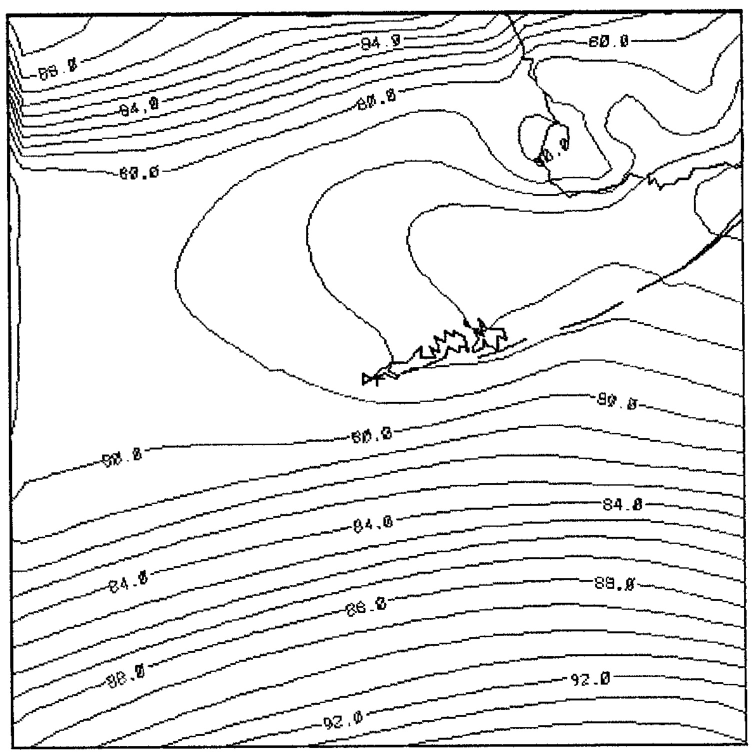


FIGURE 11: 1200 UTC 6 August 1996, Initialized Surface RH. Compare to Figure 12.



(a)



(b)

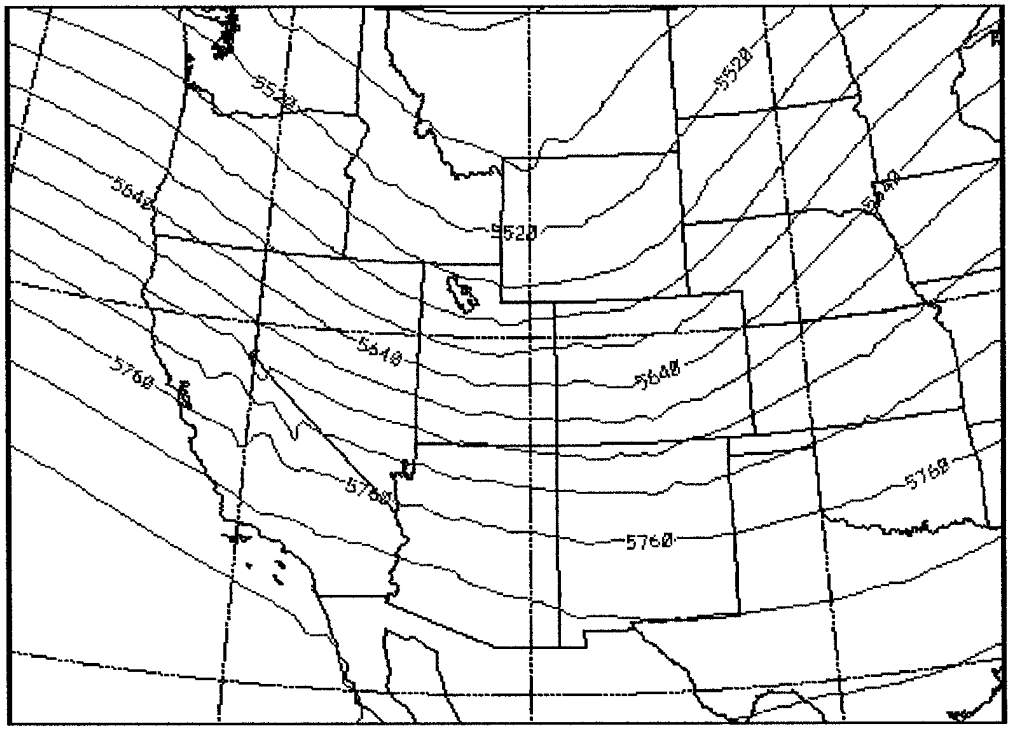
Figure 12: Forecasted Surface RH. (a) 0000 UTC 7 August 1996. (b) 1200 UTC 7August 1996.

intervals are one percent, which tend to exaggerate the fields. As the forecast progressed from the initialization to the 24-hour forecast, the RH field started to take on a strong ridge feature along the spine of the Florida Keys. This is due to improperly analyzed sea surface temperatures, combined with the effect of four dimensional data assimilation, nudging the model towards the observations. This is not a desirable feature, but it did not significantly impact the forecasts made. Even though the ocean surface was poorly parameterized, the data assimilation helped to mitigate the effects in the immediate vicinity of Key West. There may also have been some boundary effects, as evidenced by the strong kinks in the isopleths near the grid 3 boundary.

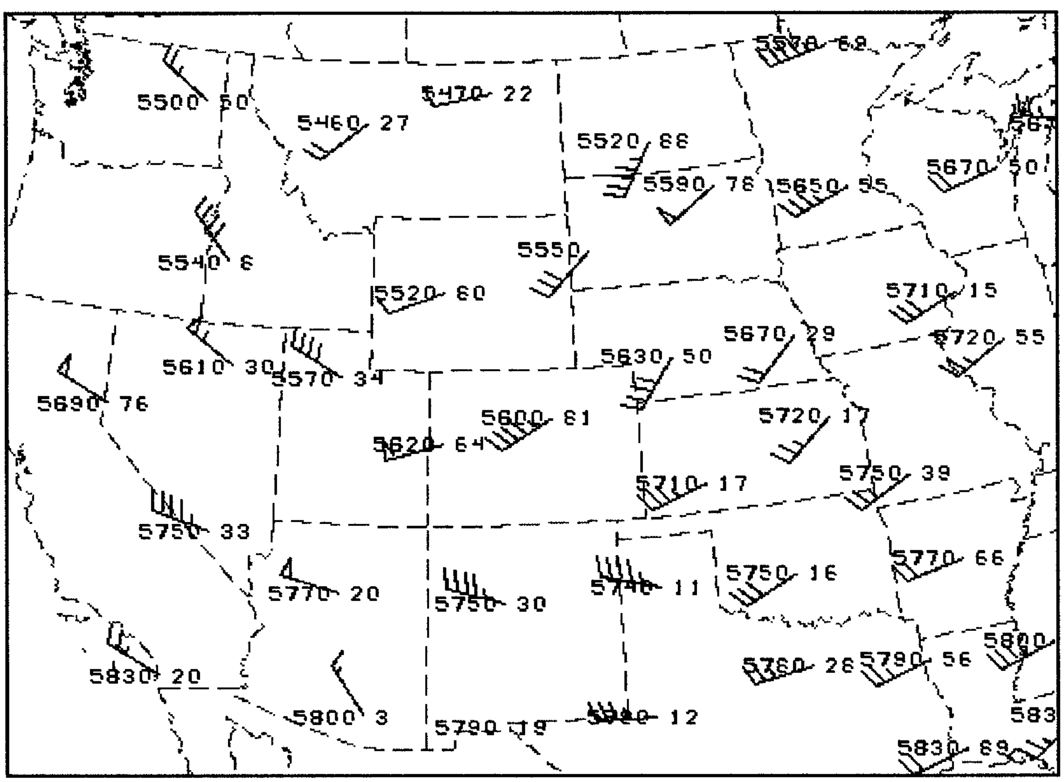
The observed PBL height was 11,100 m while the forecasted PBL height was 8,500 m, which is Category 2. PIMIX returned a forecasted value of 10,191 m, which was also Category 2. POTEMP, RICH, and TKE were 879, 400, and 863 m, respectively, and were misses. This case illustrates the ability of PIMIX to accurately assess deep, moist convection. Notice that the other algorithms returned values consistent with the cloud bases (about 900 hPa). The hand-analysis was based on where the temperature lapse rate became slightly greater than moist-adiabatic, at the same height where the winds started backing with height (at approximately 400 hPa).

f. Case Study II. 0000 UTC 17 October 1996, at Grand Junction, Colorado

This 0000 UTC 17 October 1996 case was the 24-hour forecast point and represents one where the algorithms did not generate accurate PBL estimates, even though RAMS did a good job forecasting the overall weather pattern. A look at the 500 hPa geopotential heights shows a strong trough over the central Rockies. Comparing this

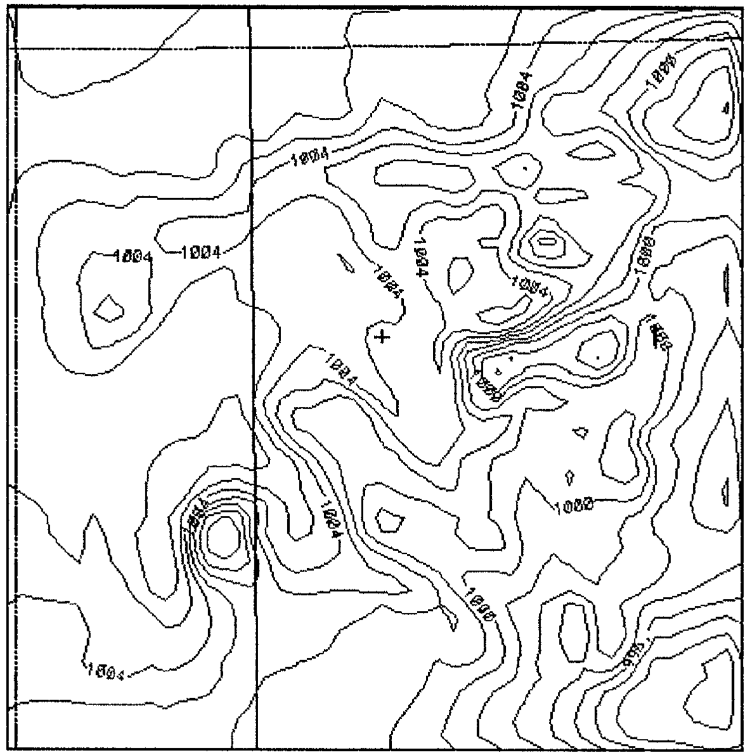


(a)

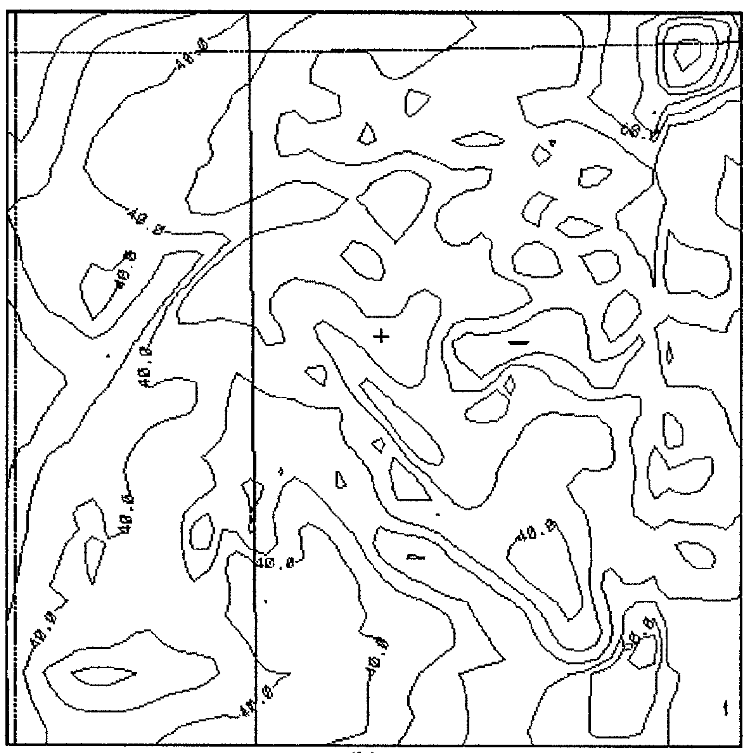


(b)

FIGURE 13: 0000 UTC 17 October 1996, 500 hPa Geopotential heights (m). (a) Forecasted geopotential heights. (b) Observed geopotential heights and RH.



(a)



(b)

FIGURE 14: 0000 UTC 17 October 1996, Surface Forecast. (a) MSPL (hPa). (b) RH isoplethed every 5 percent. Box size is 255 by 255 km centered on GJT.

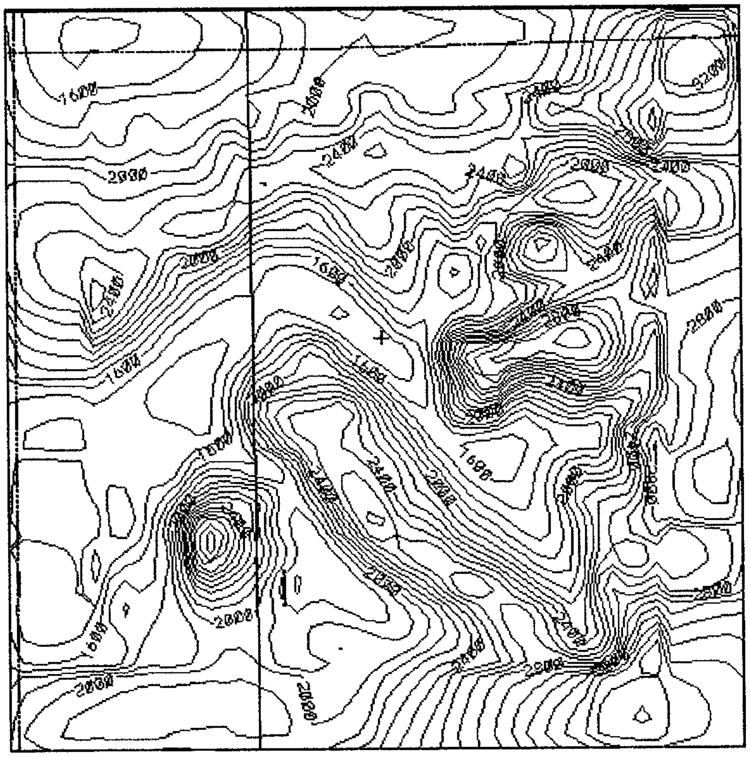
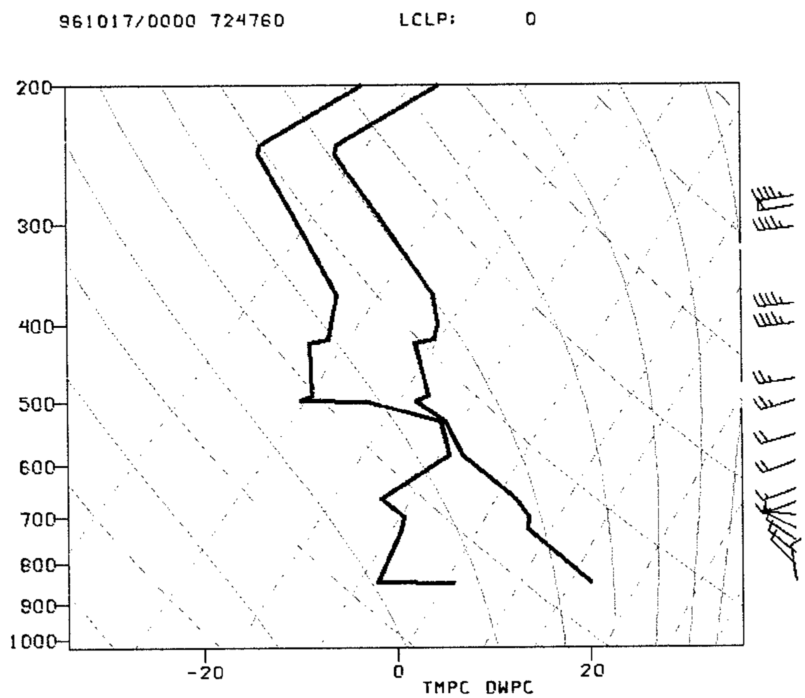


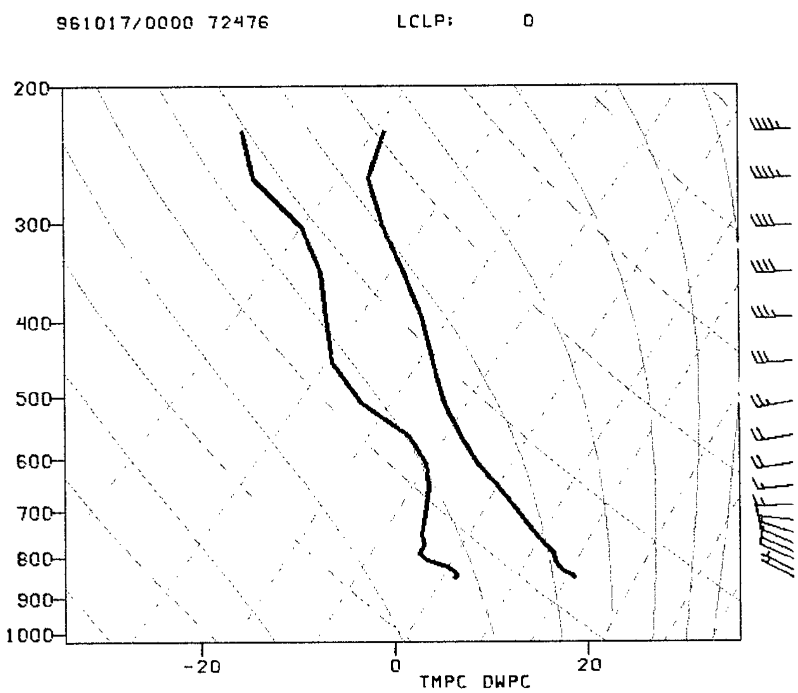
FIGURE 15: GJT Topography. Terrain height (m). Box size as in Figure 14.

to the 500 hPa observation shows RAMS was fairly accurate (Figure 13). The surface observed mean sea level pressure (MSLP) and RH (not shown) compared well to the forecasted values, but the forecasted MSLP and RH fields were very chaotic, due to the terrain (Figures 14 and 15). Note the boundary effects on the edges of the surface MSLP and RH fields. The soundings, however, did not compare as well (see Figure 16).

There are considerable differences between the observed and forecasted soundings. Most of these can be attributed to the areal and vertical averaging the model-derived soundings had. The observed PBL height was 1,530 m (AGL). The hand-analyzed PBL height was 506 m. PIMIX estimated a value of 4,524 m, while POTEMP, RICH, and TKE estimated 500, 500, and 397 m respectively. Notice the observed PBL



(a)



(b)

FIGURE 16: 0000 UTC 17 Oct 1996, Skew-*T*s at GJT. (a) Observed. (b) Forecasted.

height corresponds to the slight break in the temperature sounding around 740 hPa. A similar feature is found on the forecasted skew-*T*, but at the 840 hPa level, which corresponds to the hand-analyzed, forecasted PBL height. This case illustrates how PIMIX can grossly overestimate the PBL height because of the smoother, forecasted soundings.

5. *Conclusions and Recommendations*

a. Overview

This chapter is broken into two sections. The first part summarizes principle conclusions from the previous chapter. The second part makes recommendations based upon these conclusions. It also presents recommendations for future research which would help improve AFTAC's modeling efforts.

b. Summary of Conclusions

1) Analysis

In the analysis, the three SLAM algorithms were input observed soundings from which they generated PBL height estimates. These estimates were compared to hand-analyzed PBL heights from the observed soundings, taken to be the observed "truth." The algorithms' performances were ranked based on which algorithm had the statistically significant, greatest number of hits. If two or more algorithms had a statistically similar number of hits, then the algorithm with the greatest number of estimates indicative of deep convection was ranked better.

In this study, the PIMIX algorithm proved itself superior, or equal, to all other algorithms when used as an analysis tool (upon observed soundings) in all geophysical regimes. PIMIX also had the lowest number of failures of any of the algorithms. POTEMP was as accurate as PIMIX in dry environments; however, POTEMP was unable to accurately handle tropical airmasses. RICH had the poorest performance at all stations.

2) Simulation

In simulation, the three SLAM algorithms and the TKE algorithm were input RAMS forecasted soundings, from which they made PBL height estimates. These were compared to hand-analyzed PBL heights made from the RAMS forecasted soundings. The algorithms were ranked as in the analysis, to determine which algorithm was most accurate within the modeling environment.

Unexpectedly, POTEMP and TKE performed equally well and superior, or equal, to the other two algorithms in all regimes. PIMIX was much better at showing the presence of deep convection but seemed to consistently overestimate PBL heights in the presence of moisture, resulting in lower hit rates. However, PIMIX had accuracy similar to POTEMP and TKE at Vandenburg AFB and North Platte. RICH had the poorest performance at all stations.

3) Verification

For verification, the algorithms' outputs from the simulation were compared to the observed "truths" from the analysis. The algorithms' performances were ranked as before to determine which model-algorithm combination produced the greatest number of hits.

Overall, PIMIX verified best, but not because of its hit rate. It was equal to the other three algorithms in hit rate, but superior in indicating deep convection. In the simulation, PIMIX was ranked lower than in the verification. This points to a possible systematic error with the method used to hand-analyze the forecasted soundings that favored PIMIX and POTEMP. However, the hand-analyzed forecasted soundings consistently verified better than any of the algorithms at all of the stations. This indicates that even if there is a problem with the method used to hand-analyze the forecast soundings, it is not completely responsible for the difference in performance PIMIX had between observed and forecasted soundings.

c. Recommendations

1) Algorithm Selection

Based on the conclusions of this research, PIMIX should be used exclusively to analyze observed soundings. It is the most accurate algorithm by far. For modeling purposes, PIMIX, TKE, and POTEMP should be used as an ensemble. When all three returned a similar value, there was a high degree of accuracy. If PIMIX indicates a significantly higher value than the other two, there is a possibility that deep convection occurred in the scenario being modeled. Further attention should be given to the model output to confirm the presence of convection.

2) Future Research Opportunities

During the course of this project, several opportunities for further research became evident. Some are improvements to algorithms, and others are to help clear up some model configuration issues.

While PIMIX was the best verified algorithm, there is room for improvement. Part of the definition of the PBL is that wind speed and direction tend to be the same within the PBL (Mason 1989; Kaimal et al. 1976). This fact was used to help make the hand-analyses. It would be interesting to see if adding this into PIMIX would improve the algorithm's performance.

Combining PIMIX and POTEMP would make for an even better algorithm. Basically, POTEMP should be used until the sounding is saturated, at which point the PIMIX logic would take over. It seemed that PIMIX would return high PBL estimates when the temperature lapse rate was nearly moist-adiabatic, no matter how dry the sounding was, resulting in a gross overestimation of the PBL height in some cases.

The TKE algorithm shows a lot of promise, but it is not yet fully developed. The theory behind TKE suggests there should exist a tight gradient at the top of the PBL, going from high values of TKE within the PBL to low values in the free atmosphere (Mason 1989). The TKE post-processing algorithm only looks for a preset value of TKE to use as a threshold. Changing the algorithm to look for this tight gradient of TKE values might yield better results. Another improvement to the TKE algorithm would include the capability to interpolate the PBL height between model levels. Currently, the model returns the height of the model level at which the TKE value first falls below the threshold. In the model setup used in this research, this was close to 100 m. Thus, in order to be classified as a hit, the model's PBL height had to be either the level below or above the observed height. Greater accuracy might be achieved by interpolating to the height of the threshold value between model layers.

There were several issues that came up during the setup of this research, regarding model configuration, that need to be answered. Warner et al. (1997) highlights some of the problems limited-area, nested grid models have because of boundary interactions. In their paper, lower resolution, non-nested grid configurations usually had higher forecast accuracy for certain parameters by eliminating sub-grid boundary interactions. It may be that forecast accuracy of soundings could be increased by eliminating the 5 km sub-grid within the configuration. Then again, the effect of eliminating this grid on the accuracy of other fields, such as wind, is not known. Determining an optimal model setup and documenting its strengths, weaknesses, and accuracy is needed.

Finally, actual forecast hit rates should be computed for PIMIX, POTEMP, and TKE based on direct measurement of the PBL height (using LIDAR or a similar vertical sounder). Hopefully, this will be done after some of the above-mentioned improvements have been made.

Appendix A: RAMS Configuration Specifications

The following technical description of the four different RAMS configurations used for this research was compiled from information provided by Devin B. Dean of ENSCO, Inc., 445 Pineda Court, Melbourne, Florida 32940.

The Regional Atmospheric Modeling System (RAMS, Pielke et al. 1992) was used to produce accurate high resolution forecast fields over the region of interest using a configuration appropriate for transport and diffusion studies. The grid configuration for each of the five sounding locations is depicted in Table A1.

TABLE A1: RAMS Grid Configurations. Number of X and Y points refer to the number of grid points in the east-west and north-south directions, respectively. Horizontal spacing is the distance between grid points. The West configuration contains Vandenburg AFB, California and Grand Junction, Colorado.

Configuration	Grid Number	Number X Points	Number Y Points	Horizontal Spacing (km)	Center Latitude (N)	Center Longitude (W)
Key West, Florida	1	35	40	100	24.55	81.75
	2	90	82	25	24.55	81.75
	3	52	52	5	24.55	81.75
Lake Charles, Louisiana	1	35	40	100	30.00	93.00
	2	94	82	25	30.00	93.00
	3	52	52	5	30.00	93.50
North Platte, Nebraska	1	50	40	100	41.00	101.00
	2	122	82	25	41.00	101.00
	3	52	52	5	41.00	101.00
"West"	1	50	40	100	40.00	115.00
	2	126	90	25	39.00	111.00
	3	52	52	5	34.70	120.60
	4	52	52	5	39.00	108.50

All of the grids utilized the same vertical configuration, employing 30 vertical levels with an initial spacing of 100 meters stretching to 1,000 m at the model top, located near 20 km. Communication between the nested grids was accomplished using the model's 2-way interactive nesting scheme described by Clark and Farley (1984) and Clark and Hall (1991).

The cumulus parameterization activated on the 100 and 25 km mesh grids is a modification of the Kuo (1974) scheme described by Molinari (1985). The full microphysics package available in the model was utilized; parameterization of all rain and ice microphysical species available in the model was activated. Long and shortwave radiation was parameterized using the scheme developed by Chen and Cotton (1988).

RAMS allows the user to input spatially varying datasets into the model for the purposes of defining the lower boundary. Topographical data were specified at 10 arc minute resolution (approximately 18.5 km) on the outer two grids, while on the inner grids 9 arc second resolution (approximately 300 m) topography data were used. Climatological sea surface temperatures specified at 10 arc minutes defined the water temperatures where appropriate, and land percentage data specified at 10 arc minutes resolution defined the land/sea interface.

Meteorological data are input to the model using the RAMS isentropic analysis package (ISAN, Tremback 1990). This package reads the available gridded, surface, and upper-air observations to produce initial and lateral boundary conditions at 12 hourly intervals (e.g. 0000 and 1200 UTC). Gridded data from the NCEP/NCAR Reanalysis Project (Kalnay et al. 1996), and regular surface and upper-air observations available from the U.S. Air Force Global Weather Center were used in this study. Gross error checks, hydrostatic, and wind shear criteria quality control were applied to these data prior to ingestion by ISAN. Analyses were prepared for the 100 and 25 km mesh grids; the 5 km mesh grids were initialized by interpolation from the 25 km mesh grid.

To control error growth, four dimensional data assimilation (4DDA, Stauffer and Seaman 1990) was used on the 100 km mesh grids using the ISAN produced 12 hourly analyses of the u and v wind components, potential temperature, and water vapor mixing ratio. The nudging time scale used over the majority of the model domain was a relatively weak 3 hours; a stronger time scale (approximately 25 minutes) was used along the lateral boundaries of the 100 km grid.

Appendix B: RAMS TKE Post-Processing Program Code

This is a partial listing of the RAMS post-processing program *rcomp.f,* as provided by Devin B. Dean of ENSCO, Inc., 445 Pineda Court, Melbourne, Florida 32940. This particular code computes the height of the PBL from outputted fields of TKE.

Array *a* contains the 3-D TKE fields.
Array *c* contains the 3-D pressure fields.
n1 , n2, and n3 are number of grid points in the x, y, and z direction, respectively.

```
entry RAMS_comp_pbl(n1,n2,n3,a,c,ngrd)
         tkethrsh=0.001    !tke threshold for PBL height in m2/s2
         do j=1,n2
            do i=1,n1
               pblht=0.
               do k=2,n3
                  pblht=ztn(k,ngrd)*(1.-c(i,j,1)/zmn(nnzp(1)-1,1))
c                  if(i.ge.10.and.i.le.25.and.j.ge.13.and.j.le.25)
c     &                 print*,'i,j,k,z,pbl=',i,j,k,ztn(k,ngrd),pblht
                  if(a(i,j,k).le.tkethrsh)goto 10
               enddo
 10            continue
               do k=1,n3
                 a(i,j,k)=pblht
               enddo
            enddo
         enddo
c         call cpezct(a(i,j,2),n1,n2)
      return
```

Appendix C: Filtered Observations Around Lake Charles, Louisiana and Key West, Florida

This Appendix contains observations from the vicinity of Lake Charles and Key West. Present weather, 6-hour precipitation, low-, mid-, and high-cloud types were used to filter the observations by eliminating those reports without at least one of these fields.

TABLE C1: Filtered Observations around Lake Charles, Louisiana and Key West, Florida. WMO is World Meteorological Organization Station Number (names in Legend at the end of the table); Date in YYMMDD format; TIME in UTC; WX is the WMO weather code (see Legend); P06 is 6-hour precipitation (1/100th of inches); Low, Mid, and High are the low-, mid-, and high-cloud types (see Legend).

WMO	DATE	TIME	WX	P06	Low	Mid	High
722026	960408	600	0	M	0	7	0
722390	960408	600	0	M	0	5	0
722015	960408	900	M	M	0	7	0
722026	960408	900	M	M	5	7	0
722390	960408	900	M	M	0	3	0
722015	960408	1200	0	M	1	7	0
722390	960408	1200	0	M	0	7	9
722015	960408	1500	M	M	2	7	2
722026	960408	1500	M	M	8	7	M
722026	960408	1800	0	M	8	7	M
722015	960408	2100	0	M	5	7	2
722026	960408	2100	6	M	1	7	7
722015	960409	300	M	M	0	7	7
722026	960409	300	M	M	0	7	M
722015	960409	600	0	M	5	7	M
722026	960409	600	0	M	5	7	M
722015	960409	900	M	M	5	7	7
722026	960409	900	M	M	5	7	7
722390	960409	900	M	M	0	7	0
722015	960409	1200	0	M	0	7	M
722026	960409	1200	0	M	5	7	7
722390	960409	1200	0	M	0	7	0
722015	960418	1800	0	M	1	0	1
722026	960418	1800	0	M	1	0	1
722390	960418	1800	1	M	2	0	0
782290	960418	1800	0	5	2	0	2
722015	960418	2100	M	M	1	0	0
722026	960418	2100	M	M	1	0	1
722390	960418	2100	M	M	5	0	0
782290	960418	2100	0	5	1	0	2
722026	960419	0	0	M	1	0	0
722390	960419	0	0	M	2	0	1
722026	960419	300	M	M	5	0	0

TABLE C1: Continued.

WMO	DATE	TIME	WX	P06	Low	Mid	High
722390	960419	300	M	M	6	0	0
722026	960419	600	0	M	5	0	0
722390	960419	600	0	M	5	0	0
722026	960419	900	M	M	5	0	0
722390	960419	900	M	M	5	0	0
722015	960419	1200	0	M	1	0	0
722026	960419	1200	0	M	5	0	0
722015	960419	1500	M	M	1	0	0
722026	960419	1500	M	M	5	0	0
722390	960419	1500	M	M	2	0	0
722015	960419	1800	0	M	1	0	0
722026	960419	1800	0	M	5	0	0
722390	960419	1800	0	M	1	0	0
722015	960419	2100	M	M	5	0	0
722026	960419	2100	M	M	5	0	0
722390	960419	2100	M	M	1	0	0
722015	960420	0	0	M	1	0	0
722026	960420	0	0	M	5	0	0
722390	960420	0	0	M	1	0	0
722015	960428	600	0	M	1	0	0
722026	960428	600	0	M	1	0	0
722390	960428	600	0	M	1	0	0
722015	960428	900	M	M	1	0	0
722026	960428	900	0	M	2	0	0
722390	960428	900	M	M	1	0	0
722015	960428	1200	0	M	1	0	0
722026	960428	1200	0	M	2	0	0
722390	960428	1200	0	M	1	0	1
722015	960428	1500	M	M	1	0	0
722026	960428	1500	M	M	2	0	0
722390	960428	1500	M	M	1	0	1
722015	960428	1800	0	M	1	0	0
722026	960428	1800	0	M	2	0	0
722390	960428	1800	0	M	1	0	1
722015	960428	2100	M	M	1	0	0
722390	960428	2100	M	M	1	0	1
722015	960429	0	0	M	1	0	0
722026	960429	0	0	M	1	7	0
722390	960429	0	0	M	1	0	1
722015	960429	300	M	M	2	0	0
722026	960429	300	M	M	2	7	0
722390	960429	300	M	M	8	0	0
722015	960429	600	0	M	1	0	0
722026	960429	600	0	M	1	0	0

TABLE C1: Continued.

WMO	DATE	TIME	WX	P06	Low	Mid	High
722390	960429	600	0	M	8	0	0
722010	960429	900	3	M	M	M	M
722015	960429	900	M	M	2	0	0
722026	960429	900	M	M	1	0	0
722390	960429	900	M	M	6	M	M
722015	960429	1200	0	M	8	0	1
722026	960429	1200	0	M	1	0	1
722390	960429	1200	0	M	7	M	M
722015	960508	1800	0	M	1	0	2
722026	960508	1800	0	M	1	0	1
722390	960508	1800	0	M	1	0	0
722015	960508	2100	M	M	1	0	1
722026	960508	2100	M	M	1	0	1
782290	960508	2100	0	5	2	0	0
722026	960509	0	0	M	8	0	0
782290	960509	0	0	5	9	0	0
722015	960509	300	M	M	1	0	0
722026	960509	300	M	M	8	7	0
782290	960509	300	0	5	4	0	0
722015	960509	600	0	M	1	0	0
722026	960509	600	0	M	2	0	0
722390	960509	600	0	M	5	0	0
782290	960509	600	0	5	4	0	0
722015	960509	900	M	M	8	0	0
722026	960509	900	1	M	2	7	0
722390	960509	900	M	M	5	M	M
782290	960509	1100	0	5	4	0	0
722015	960509	1200	0	M	1	0	1
722026	960509	1200	1	M	1	0	1
782290	960509	1200	0	5	1	0	0
722026	960509	1500	M	M	2	0	1
722390	960509	1500	M	M	1	0	6
782290	960509	1500	M	5	2	0	0
722015	960509	1800	0	M	1	0	7
722026	960509	1800	0	M	2	0	1
722390	960509	1800	0	M	2	0	0
782290	960509	1800	M	5	2	0	0
722015	960509	2100	M	M	1	0	7
722026	960509	2100	M	M	2	0	1
722390	960509	2100	M	M	3	M	0
782290	960509	2100	M	5	9	6	3
722015	960510	0	0	M	2	0	7
722026	960510	0	0	M	2	7	1
722390	960510	0	0	M	5	0	0

TABLE C1: Continued.

WMO	DATE	TIME	WX	P06	Low	Mid	High
782290	960510	0	M	5	2	6	2
722015	960518	600	0	M	1	0	2
722026	960518	600	0	M	1	0	1
722390	960518	600	0	M	6	0	0
722015	960518	900	M	M	5	0	2
722026	960518	900	M	M	4	0	1
722390	960518	900	M	M	6	0	0
722015	960518	1200	0	M	2	7	7
722390	960518	1200	0	M	6	M	M
722015	960518	1500	M	M	1	7	1
722026	960518	1500	M	M	1	7	8
722390	960518	1500	M	M	5	0	0
722015	960518	1800	0	M	1	7	8
722026	960518	1800	0	M	4	7	7
722390	960518	1800	0	M	1	0	0
722015	960518	2100	M	M	1	7	8
722026	960518	2100	M	M	4	7	7
722390	960518	2100	M	M	1	0	0
722015	960519	0	0	M	1	7	8
722026	960519	0	0	M	1	7	7
722390	960519	0	0	M	1	0	0
722015	960519	300	M	M	1	7	M
722026	960519	300	M	M	1	7	M
722015	960519	600	0	M	1	7	0
722026	960519	600	0	M	1	7	M
722015	960519	900	1	M	1	0	1
722026	960519	900	0	M	8	0	0
722390	960519	900	M	M	6	0	0
722015	960519	1200	1	M	2	7	0
722026	960519	1200	0	M	1	7	8
722390	960519	1200	0	M	6	0	0
722015	960528	1800	0	M	1	0	1
722026	960528	1800	0	M	2	0	1
722026	960528	2100	1	M	9	6	3
722390	960528	2100	M	M	1	0	1
782290	960529	200	0	5	M	M	M
722015	960529	300	M	M	1	0	1
722026	960529	300	24	M	9	M	M
722015	960529	600	0	M	1	7	1
722026	960529	600	25	M	0	7	8
722390	960529	600	0	M	6	0	7
722015	960529	900	M	M	1	0	1
722026	960529	900	M	M	0	7	8
722390	960529	900	M	M	6	M	M

TABLE C1: Continued.

WMO	DATE	TIME	WX	P06	Low	Mid	High
782290	960529	1000	0	5	4	0	0
722015	960529	1200	0	M	1	0	1
722026	960529	1200	0	M	0	7	8
722390	960529	1200	0	M	5	M	M
782290	960529	1200	0	5	4	0	0
722015	960529	1500	M	M	8	0	1
722026	960529	1500	M	M	1	0	1
722390	960529	1500	M	M	5	M	M
722015	960529	1800	0	M	8	0	1
722026	960529	1800	12	M	3	0	3
722015	960529	2100	M	M	8	0	0
722026	960529	2100	5	M	9	0	7
722390	960529	2100	M	M	9	0	7
722015	960530	0	0	M	2	0	1
722026	960530	0	5	M	2	7	7
722390	960530	0	0	M	9	2	M
722410	960530	0	2	M	M	M	M
722015	960607	600	0	M	5	0	0
722026	960607	600	0	M	1	7	0
722015	960607	900	M	M	1	3	1
722026	960607	900	M	M	2	7	0
722390	960607	900	M	M	0	7	0
722015	960607	1200	0	M	1	3	1
722026	960607	1200	0	M	2	0	1
722390	960607	1200	0	M	1	7	1
782290	960607	1200	M	5	2	6	2
722015	960607	1500	M	M	1	3	1
722026	960607	1500	M	M	2	0	1
722015	960607	1800	0	M	2	0	1
722026	960607	1800	0	M	2	0	1
722015	960607	2100	0	M	2	0	0
722026	960607	2100	M	M	9	6	3
722390	960607	2100	M	M	9	0	3
722010	960608	0	9	M	M	M	M
722026	960608	0	0	M	5	7	8
722390	960608	0	1	M	9	7	2
722026	960608	300	0	M	2	7	0
722390	960608	300	M	M	4	6	0
722026	960608	600	0	M	5	0	0
722015	960608	900	M	M	8	0	0
722026	960608	900	M	M	5	0	0
722015	960608	1200	0	M	2	3	1
722026	960608	1200	0	M	2	7	1
722390	960608	1200	0	M	0	7	0

TABLE C1: Continued.

WMO	DATE	TIME	WX	P06	Low	Mid	High
722015	960617	1800	9	M	3	7	1
722026	960617	1800	0	M	9	6	3
722390	960617	1800	0	M	2	0	0
782290	960617	1800	M	5	9	0	3
722015	960617	2100	M	M	3	7	1
722026	960617	2100	M	M	9	6	3
722390	960617	2100	M	M	9	6	3
722015	960618	0	1	M	3	6	3
722026	960618	0	0	M	2	6	3
722390	960618	0	0	M	2	6	3
722026	960618	300	M	M	2	0	3
722390	960618	300	M	M	0	7	3
722015	960618	600	0	M	1	0	0
722015	960618	900	M	M	1	0	0
722026	960618	900	M	M	1	7	8
722026	960618	1200	0	M	9	6	3
782290	960618	1200	M	5	2	7	2
722015	960618	1500	M	M	3	7	1
722026	960618	1500	0	M	1	7	8
722390	960618	1500	M	M	1	7	1
782290	960618	1700	0	5	9	0	2
722015	960618	1800	0	M	8	0	1
722026	960618	1800	0	M	2	0	1
722390	960618	1800	0	M	1	0	0
722015	960618	2100	M	M	8	7	1
722026	960618	2100	0	M	2	6	3
722390	960618	2100	M	M	9	6	3
782290	960618	2100	0	95	9	2	M
722015	960619	0	1	M	1	7	6
722026	960619	0	60	M	9	6	3
722390	960619	0	0	M	9	6	3
722015	960627	600	0	M	1	7	0
722026	960627	600	0	M	3	0	2
722015	960627	900	M	M	3	7	0
722026	960627	900	M	M	2	0	2
722015	960627	1200	0	M	9	7	3
722026	960627	1200	0	M	1	0	1
722390	960627	1200	0	M	2	7	1
782290	960627	1200	M	10	2	0	0
722015	960627	1500	M	M	3	7	2
722026	960627	1500	M	M	3	0	2
722390	960627	1500	M	M	0	3	9
722015	960627	1800	0	M	2	7	3
722026	960627	1800	31	M	9	6	3

TABLE C1: Continued.

WMO	DATE	TIME	WX	P06	Low	Mid	High
722390	960627	1800	0	M	1	5	9
722015	960627	2100	M	M	2	7	3
722390	960627	2100	M	M	1	7	1
722015	960628	0	0	M	3	7	3
722026	960628	0	1	M	2	6	3
722390	960628	0	0	M	9	7	3
722015	960628	300	M	M	2	7	3
722026	960628	300	M	M	0	6	3
722390	960628	300	0	M	0	7	3
722400	960628	300	21	M	M	M	M
722015	960628	600	0	M	2	0	1
722400	960628	600	22	M	0	0	0
722410	960628	600	1	M	M	M	M
722015	960628	900	M	M	2	0	1
722026	960628	900	M	M	0	0	1
722015	960628	1200	0	M	2	0	1
722026	960628	1200	0	M	1	0	2
722390	960628	1200	0	M	5	7	1
782290	960707	1800	0	5	2	0	2
782290	960707	2100	0	0	2	0	2
722400	960708	0	2	95	M	M	M
782290	960708	0	0	5	9	0	2
782290	960708	300	0	5	2	0	2
782290	960708	600	0	5	2	0	2
782290	960708	900	0	5	2	0	2
782290	960709	0	M	5	9	6	3
722410	960717	1153	2	M	M	M	M
722390	960717	1200	37	M	M	M	M
722400	960717	1200	0	10	M	M	M
722400	960717	1800	0	95	M	M	M
722410	960718	1153	8	M	M	M	M
722026	960718	1200	2	M	M	M	M
782290	960727	2000	0	5	2	0	0
782290	960727	2300	0	5	2	0	0
782290	960728	300	0	5	2	0	0
782290	960728	800	0	5	2	0	2
782290	960728	1500	M	5	2	0	0
782290	960728	1800	M	5	2	0	0
722010	960729	0	3	0	M	M	M
782290	960729	0	M	5	9	0	3
722010	960806	600	0	95	M	M	M
722010	960806	1200	3	0	0	0	0
722026	960806	1200	4	M	M	M	M
722400	960806	1200	0	10	M	M	M

TABLE C1: Continued.

WMO	DATE	TIME	WX	P06	Low	Mid	High
782290	960806	1200	M	10	9	6	3
722010	960806	1800	0	61	M	M	M
722410	960807	1153	22	M	M	M	M
722015	960807	1200	1	M	M	M	M
722400	960807	1200	0	10	0	0	0
722010	960816	1800	1	0	M	M	M
722400	960816	1800	0	5	M	M	M
722010	960817	0	40	0	0	0	0
722400	960817	0	3	5	0	0	0
722400	960817	600	0	10	0	0	0
722410	960817	1153	2	M	M	M	M
722400	960817	1200	0	10	0	0	0
782290	960817	1200	M	5	2	6	2
722010	960817	1800	21	M	0	0	0
782290	960826	1200	M	5	9	6	3
722015	960827	1200	5	M	M	M	M
722026	960827	1200	5	M	M	M	M
722400	960906	0	0	95	M	M	M
722400	960906	1200	0	10	0	0	0
722400	960907	0	4	0	M	M	M
722400	960915	600	0	10	0	0	0
722400	960915	1200	0	10	0	0	0
722010	960915	1800	1	0	0	0	0
722010	960916	0	59	0	M	M	M
722400	960916	0	1	0	0	0	0
722410	960916	1153	7	M	M	M	M
722015	960916	1200	8	M	M	M	M
722026	960916	1200	2	M	M	M	M
782290	960916	1200	M	5	9	0	3
722010	960925	1800	3	0	0	0	0
722010	960926	600	0	61	M	M	M
722026	960926	1200	10	M	M	M	M
722400	960926	1200	0	10	0	0	0
722010	960927	0	7	61	M	M	M
722015	961005	1200	1	M	M	M	M
722400	961005	1200	0	61	M	M	M
782290	961005	1200	M	5	9	6	3
722010	961005	1800	0	61	M	M	M
722400	961005	1800	1	0	M	M	M
782290	961005	2300	0	60	9	2	2
722010	961006	0	27	61	M	M	M
722400	961006	0	1	61	M	M	M
782290	961006	300	0	80	2	4	M
722010	961006	600	72	63	M	M	M

TABLE C1: Continued.

WMO	DATE	TIME	WX	P06	Low	Mid	High
782290	961006	600	0	5	2	6	2
782290	961006	900	0	5	2	6	2
722410	961006	1153	3	M	M	M	M
722010	961006	1200	5	0	M	M	M
722015	961006	1200	106	M	M	M	M
722026	961006	1200	2	M	M	M	M
722010	961016	0	1	0	0	0	0
722026	961016	1200	107	M	M	M	M
722400	961016	1200	0	10	M	M	M
722010	961017	0	14	0	0	0	0
722400	961025	600	82	95	M	M	M
722410	961025	1153	57	M	M	M	M
722390	961025	1200	43	M	M	M	M
722400	961025	1200	9	63	M	M	M
722400	961025	1800	5	61	M	M	M
722400	961026	0	95	65	M	M	M
722400	961026	600	26	0	M	M	M
722410	961026	1153	29	M	M	M	M
722390	961026	1200	26	M	M	M	M

Legend

WMO	WX	L,M,H	Low Cloud	Mid Cloud	High Cloud
5	Haze	1	Fair wx Cu	Thin As	Mare's Tails Ci
10	Lt Fog	2	Towering Cu	Thick As	Dense Ci – patches
60	Int Lt Rain	3	Cb, w/o anvil	Thin Ac-semi trans	Ci anvils from Cb
61	Cont Lt Rain	4	Sc from Cu	Thin Ac –patchy	Ci – spreading
63	Cont Drizzle	5	Sc not from Cu	Thin Ac – spreading	Ci or Cs < 45°
65	Cont Heavy Rain	6	St or Fs, not bad wx	Ac from Cu	Ci or Cs > 45 °
80	Lt Rain Swr	7	Fs or Fc of bad wx	Think Ac or Ns	Veil of Cs
95	Mod TS	8	Cu and Sc	Ac with turrets	Cs
		9	Cb with anvil	Ac - Chaotic	Cc

This Appendix contains the hand-analyzed PBL heights from the observed soundings used for the Analysis. The three SLAM algorithms' PBL estimates, and their RMS error categorizations are presented. All dates are in 1996.

TABLE D1: Analysis Results for Key West, Florida. Time is either 00 for 0000 UTC or 12 for 1200 UTC. Obs is the hand-analyzed observed PBL heights, while PIMIX, POTEMP, and RICH are the PBL estimates for the respective algorithms. Cat 1 is a hit, Cat 2 indicates deep convection, Cat 3 is a miss, and Cat 4 is an algorithm failure. Missing data is indicated by m.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
10Jan/00	550	555	1	555	1	600	1
10Jan/12	800	100	3	849	1	400	3
11Jan/00	600	1175	3	643	1	1600	3
19Jan/12	4000	4014	1	1095	3	700	3
20Jan/00	400	401	1	401	1	300	1
20Jan/12	350	396	1	397	1	100	3
30Jan/00	1700	1759	1	1153	3	900	3
30Jan/12	1650	1705	1	1116	3	400	3
31Jan/00	1600	3733	3	676	3	-500	4
08Feb/12	1850	1882	1	815	3	1600	3
09Feb/00	1500	1539	1	1539	1	1600	1
09Feb/12	100	1529	3	1450	3	100	1
19Feb/00	1250	1286	1	725	3	500	3
19Feb/12	1100	1117	1	1118	1	100	3
20Feb/00	1150	1036	3	1037	3	400	3
28Feb/12	700	714	1	714	1	100	3
29Feb/00	300	370	1	371	1	300	1
29Feb/12	2150	1962	3	1377	3	100	3
10Mar/00	950	1012	1	1013	1	300	3
10Mar/12	600	614	1	648	1	400	3
11Mar/00	1350	1399	1	1446	1	100	3
19Mar/12	2400	2448	1	2449	1	-500	4
20Mar/00	1100	1089	1	1090	1	1000	1
20Mar/12	1550	1578	1	1579	1	900	3
30Mar/00	450	532	1	563	3	-500	4
30Mar/12	550	555	1	556	1	-500	4
31Mar/00	350	352	1	353	1	400	1
08Apr/12	350	292	1	1800	3	-500	4
09Apr/00	100	1393	3	1394	3	400	3
09Apr/12	5200	5317	1	1529	3	400	3
19Apr/00	900	996	1	997	1	500	3
19Apr/12	950	956	1	956	1	1000	1

TABLE D1: Continued.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
20Apr/00	1050	1051	1	1052	1	1100	1
28Apr/12	950	1733	3	1102	3	-500	4
29Apr/00	4200	4370	1	553	3	600	3
29Apr/12	800	1985	3	897	1	800	1
09May/00	800	2526	3	865	1	700	1
09May/12	1650	1696	1	1146	3	400	3
10May/00	4100	4110	1	689	3	400	3
18May/12	1050	6259	3	1123	1	400	3
19May/00	1800	1867	1	725	3	600	3
19May/12	5800	4578	2	1305	3	400	3
29May/00	m	m	m	m	m	m	m
29May/12	450	4105	3	508	1	400	1
30May/00	900	4411	3	911	1	700	3
07Jun/12	1700	1775	1	751	3	100	3
08Jun/00	2400	2497	1	1121	3	100	3
08Jun/12	700	776	1	718	1	600	1
18Jun/00	13000	8057	2	723	3	400	3
18Jun/12	5400	5460	1	1784	3	400	3
19Jun/00	9100	9134	1	966	3	200	3
27Jun/12	800	8098	3	834	1	100	3
28Jun/00	10300	4977	2	1084	3	100	3
28Jun/12	1200	1240	1	1179	1	400	3
08Jul/00	1000	1740	3	1095	1	700	3
08Jul/12	m	-500	m	-500	m	-500	m
09Jul/00	2100	6122	3	656	3	400	3
17Jul/12	3900	4108	1	1132	3	900	3
18Jul/00	4150	4379	1	690	3	400	3
18Jul/12	2050	2197	3	1140	3	400	3
28Jul/00	1200	1216	1	1216	1	400	3
28Jul/12	9750	3798	2	786	3	400	3
29Jul/00	12500	2227	3	1148	3	200	3
06Aug/12	13500	12904	2	668	3	1000	3
07Aug/00	11000	1686	3	677	3	500	3
07Aug/12	11100	8300	2	1123	3	400	3
17Aug/00	m	-500	m	-500	m	-500	m
17Aug/12	7600	7767	1	1066	3	600	3
18Aug/00	8100	7528	2	1336	3	800	3
26Aug/12	13500	7878	2	1064	3	-500	4
27Aug/00	13200	5895	2	589	3	400	3
27Aug/12	12600	2748	3	1078	3	-500	4
06Sep/00	4400	4462	1	1042	3	100	3
06Sep/12	750	736	1	736	1	100	3
07Sep/00	1050	3406	3	1036	1	400	3
15Sep/12	7300	1293	3	1294	3	-500	4

TABLE D1: Continued.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
16Sep/00	5700	5853	1	409	3	400	3
16Sep/12	5700	5509	1	845	3	400	3
26Sep/00	11800	5063	2	824	3	600	3
26Sep/12	3100	3017	1	942	3	-500	4
27Sep/00	14300	3424	2	1062	3	-500	4
05Oct/12	14600	2524	3	1072	3	400	3
06Oct/00	15000	14832	1	1065	3	-500	4
06Oct/12	13800	2964	3	391	3	400	3
16Oct/00	5400	5434	1	1103	3	400	3
16Oct/12	5450	5499	1	346	3	400	3
17Oct/00	4750	4685	1	1083	3	400	3
25Oct/12	1950	1891	1	1806	3	700	3
26Oct/00	1700	1771	1	986	3	400	3
26Oct/12	1600	1648	1	1622	1	500	3
05Nov/00	3300	3405	1	1108	3	400	3
05Nov/12	4800	1481	3	1130	3	700	3
06Nov/00	4600	4812	1	736	3	500	3
14Nov/12	1450	1515	1	1099	3	400	3
15Nov/00	3650	1884	3	1112	3	400	3
15Nov/12	2300	2354	1	403	3	800	3
25Nov/00	1600	1682	1	1683	1	400	3
25Nov/12	800	823	1	824	1	900	1
26Nov/00	800	4554	3	811	1	400	3
04Dec/12	1600	1592	1	432	3	1000	3
05Dec/00	1600	1503	1	446	3	400	3
05Dec/12	1600	1775	3	1119	3	700	3
15Dec/00	300	318	1	318	1	400	1
15Dec/12	1000	338	3	372	3	400	3
16Dec/00	1300	1345	1	441	3	400	3
24Dec/12	2450	2452	1	1585	3	-500	4
25Dec/00	900	1483	3	1068	3	100	3
25Dec/12	100	120	1	-500	4	-500	4

TABLE D2: Analysis Results for Lake Charles, Louisiana. Labels as in Table D1.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
10Jan/00	1200	1163	1	1164	1	400	3
10Jan/12	1100	1153	1	1178	1	-500	4
11Jan/00	1750	1705	1	1705	1	400	3
19Jan/12	650	639	1	639	1	600	1
20Jan/00	900	893	1	893	1	900	1
20Jan/12	100	32326	3	1444	3	400	3
30Jan/00	3000	3051	1	392	3	-500	4
30Jan/12	2200	2250	1	2185	1	1300	3
31Jan/00	200	225	1	226	1	400	3
08Feb/12	100	100	1	788	3	-500	4
09Feb/00	m	811	m	855	m	400	m
09Feb/12	100	1895	3	1863	3	-500	4
19Feb/00	2400	2387	1	987	3	-500	4
19Feb/12	1950	1984	1	1019	3	800	3
20Feb/00	100	100	1	100	1	-500	4
28Feb/12	600	607	1	387	3	600	1
29Feb/00	500	491	1	491	1	-500	4
29Feb/12	650	637	1	638	1	600	1
10Mar/00	1300	1305	1	1305	1	1000	3
10Mar/12	1550	1552	1	1552	1	800	3
11Mar/00	1800	1830	1	1831	1	-500	4
19Mar/12	1700	1758	1	1759	1	-500	4
20Mar/00	3100	3169	1	3170	1	-500	4
20Mar/12	1300	1320	1	1320	1	400	3
30Mar/00	1100	1328	3	1055	1	-500	4
30Mar/12	200	281	1	281	1	400	3
31Mar/00	1800	1783	1	333	3	100	3
08Apr/12	100	100	1	100	1	-500	4
09Apr/00	300	375	1	376	1	200	1
09Apr/12	100	100	1	100	1	100	1
19Apr/00	1400	1443	1	626	3	400	3
19Apr/12	1300	1289	1	384	3	400	3
20Apr/00	850	799	1	799	1	800	1
28Apr/12	550	570	1	556	1	400	3
29Apr/00	850	913	1	884	1	700	3
29Apr/12	4300	4293	1	2049	3	400	3
09May/00	1950	1994	1	873	3	700	3
09May/12	2250	1070	3	1115	3	400	3
10May/00	600	3910	3	643	1	600	1
18May/12	700	711	1	723	1	400	3
19May/00	1200	1390	3	1290	1	900	3
19May/12	1000	1095	1	1027	1	400	3

TABLE D2: Continued.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
29May/00	m	-500	m	-500	m	-500	m
29May/12	750	843	1	795	1	400	3
30May/00	500	492	1	493	1	500	1
07Jun/12	1000	3519	3	1008	1	100	3
08Jun/00	7200	4268	2	336	3	300	3
08Jun/12	100	100	1	100	1	400	3
18Jun/00	1800	3135	3	1104	3	900	3
18Jun/12	900	1183	3	1210	3	100	3
19Jun/00	9100	3625	2	2529	3	-500	4
27Jun/12	1300	3098	3	-500	4	100	3
28Jun/00	8500	8582	1	428	3	200	3
28Jun/12	4200	3409	2	1460	3	200	3
08Jul/00	10000	3991	2	1297	3	400	3
08Jul/12	m	-500	m	-500	m	-500	m
09Jul/00	450	5718	3	599	3	400	1
17Jul/12	100	8891	3	1098	3	100	1
18Jul/00	1650	5378	3	589	3	-500	4
18Jul/12	13400	3126	2	1435	3	900	3
28Jul/00	800	4903	3	857	1	400	3
28Jul/12	1000	1372	3	1025	1	100	3
29Jul/00	2200	4727	3	2257	1	400	3
06Aug/12	7800	7860	1	868	3	100	3
07Aug/00	11200	11674	2	381	3	300	3
07Aug/12	8300	5921	2	903	3	400	3
17Aug/00	4050	4006	1	4006	1	400	3
17Aug/12	3550	10040	2	995	3	100	3
18Aug/00	1000	1020	1	1021	1	1300	3
26Aug/12	3700	3742	1	844	3	400	3
27Aug/00	900	4173	3	868	1	800	1
27Aug/12	100	5017	3	2498	3	-500	4
06Sep/00	11000	3332	2	2724	3	-500	4
06Sep/12	10700	10663	1	2668	3	1000	3
07Sep/00	5300	5437	1	1058	3	400	3
15Sep/12	1100	5302	3	1139	1	400	3
16Sep/00	11100	2315	3	979	3	900	3
16Sep/12	1500	1586	1	1555	1	500	3
26Sep/00	2500	2668	3	1508	3	1000	3
26Sep/12	100	1136	3	1137	3	100	1
27Sep/00	1000	3633	3	949	1	700	3
05Oct/12	550	632	1	632	1	500	1
06Oct/00	900	899	1	899	1	400	3
06Oct/12	400	359	1	359	1	400	1

TABLE D2: Continued.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
16Oct/00	1450	1447	1	1433	1	100	3
16Oct/12	100	992	3	993	3	100	1
17Oct/00	1250	1330	1	721	3	400	3
25Oct/12	125	100	1	100	1	400	3
26Oct/00	900	962	1	100	3	-500	4
26Oct/12	200	1497	3	3370	3	400	3
05Nov/00	1750	1740	1	1740	1	400	3
05Nov/12	1000	1056	1	1101	3	1000	1
06Nov/00	1450	1468	1	1102	3	400	3
14Nov/12	1700	3618	3	1648	1	100	3
15Nov/00	1100	1701	3	1195	1	400	3
15Nov/12	100	1882	3	923	3	400	3
25Nov/00	6400	2925	3	1928	3	100	3
25Nov/12	1000	1010	1	1011	1	700	3
26Nov/00	950	961	1	961	1	500	3
04Dec/12	100	100	1	1182	3	1300	3
05Dec/00	450	459	1	-500	4	400	1
05Dec/12	100	100	1	100	1	400	3
15Dec/00	800	1878	3	819	1	700	1
15Dec/12	200	282	1	-500	4	400	3
16Dec/00	950	989	1	416	3	1000	1
24Dec/12	300	310	1	311	1	1300	3
25Dec/00	800	826	1	826	1	1000	3
25Dec/12	100	100	1	298	3	300	3

TABLE D3: Analysis Results for North Platte, Nebraska. Labels as in Table D1.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
10Jan/00	1500	2167	3	1575	1	1300	3
10Jan/12	100	100	1	100	1	-500	4
11Jan/00	950	2049	3	1160	3	2600	3
19Jan/12	100	100	1	100	1	100	1
20Jan/00	500	536	1	265	3	400	1
20Jan/12	100	100	1	100	1	100	1
30Jan/00	650	648	1	649	1	-500	4
30Jan/12	500	557	1	558	1	200	3
31Jan/00	550	620	1	621	1	-500	4
08Feb/12	100	856	3	857	3	700	3
09Feb/00	1050	1143	1	1144	1	700	3
09Feb/12	100	100	1	11190	3	100	1
19Feb/00	2850	2922	1	2922	1	2900	1
19Feb/12	100	100	1	4049	3	-500	4
20Feb/00	4950	7377	2	2986	3	1900	3
28Feb/12	450	100	3	514	1	500	1
29Feb/00	1150	1141	1	1142	1	700	3
29Feb/12	100	100	1	100	1	-500	4
10Mar/00	1950	1968	1	1968	1	1000	3
10Mar/12	100	100	1	100	1	100	1
11Mar/00	m	-500	m	-500	m	-500	m
19Mar/12	1400	1423	1	1424	1	800	3
20Mar/00	1250	1297	1	1297	1	1000	3
20Mar/12	100	100	1	100	1	500	3
30Mar/00	1350	771	3	818	3	200	3
30Mar/12	500	502	1	502	1	500	1
31Mar/00	1000	1042	1	1042	1	1000	1
08Apr/12	m	-500	m	-500	m	-500	m
09Apr/00	2800	2816	1	2816	1	700	3
09Apr/12	100	100	1	100	1	100	1
19Apr/00	1650	6186	3	4521	3	-500	4
19Apr/12	350	385	1	386	1	2000	3
20Apr/00	350	1917	3	441	1	2200	3
28Apr/12	650	838	3	722	1	700	1
29Apr/00	1200	1257	1	1257	1	700	3
29Apr/12	100	2964	3	1481	3	700	3
09May/00	1650	1593	1	1070	3	-500	4
09May/12	200	297	1	298	1	1100	3
10May/00	800	842	1	842	1	500	3
18May/12	100	100	1	3687	3	100	1
19May/00	1650	10615	3	4715	3	2400	3
19May/12	100	534	3	552	3	100	1

TABLE D3: Continued.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
29May/00	m	m	m	m	m	m	m
29May/12	100	1108	3	1108	3	-500	4
30May/00	1350	1352	1	945	3	800	3
07Jun/12	100	1170	3	1170	3	500	3
08Jun/00	1500	1534	1	1535	1	800	3
08Jun/12	100	1028	3	1029	3	-500	4
18Jun/00	1400	1753	3	1423	1	700	3
18Jun/12	100	100	1	526	3	300	3
19Jun/00	1400	5488	3	1401	1	800	3
27Jun/12	250	287	1	100	3	500	3
28Jun/00	700	2490	3	924	3	700	1
28Jun/12	400	376	1	-500	4	400	1
08Jul/00	3050	3054	1	1930	3	1000	3
08Jul/12	100	776	3	776	3	300	3
09Jul/00	1700	1711	1	1712	1	800	3
17Jul/12	100	100	1	100	1	100	1
18Jul/00	650	5540	3	2986	3	100	3
18Jul/12	100	5029	3	5058	3	100	1
28Jul/00	1900	4751	3	1961	1	400	3
28Jul/12	100	100	1	100	1	100	1
29Jul/00	250	645	3	645	3	400	3
06Aug/12	100	100	1	865	3	400	3
07Aug/00	1300	4782	3	1514	3	700	3
07Aug/12	100	1106	3	957	3	100	1
17Aug/00	1300	1890	3	1517	3	1300	1
17Aug/12	350	414	1	414	1	-500	4
18Aug/00	1050	1238	3	1101	1	1100	1
26Aug/12	100	8951	3	100	1	100	1
27Aug/00	900	5228	3	974	1	800	1
27Aug/12	100	799	3	100	1	100	1
06Sep/00	1550	4085	3	1636	1	700	3
06Sep/12	100	4603	3	1922	3	100	1
07Sep/00	400	449	1	450	1	500	1
15Sep/12	m	m	m	m	m	m	m
16Sep/00	600	474	3	474	3	100	3
16Sep/12	400	438	1	438	1	100	3
26Sep/00	600	683	1	683	1	600	1
26Sep/12	100	100	1	100	1	1100	3
27Sep/00	3500	3579	1	3625	1	1600	3
05Oct/12	450	476	1	100	3	800	3
06Oct/00	1600	1624	1	1670	1	700	3
06Oct/12	650	668	1	100	3	700	1

TABLE D3: Continued.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
16Oct/00	950	1025	1	1025	1	1000	1
16Oct/12	100	-500	4	-500	4	-500	4
17Oct/00	600	680	1	599	1	600	1
25Oct/12	100	1465	3	1482	3	1100	3
26Oct/00	1100	1131	1	1131	1	1400	3
26Oct/12	750	1535	3	1536	3	1000	3
05Nov/00	1300	1307	1	1307	1	1000	3
05Nov/12	100	100	1	100	1	100	1
06Nov/00	800	877	1	878	1	100	3
14Nov/12	500	546	1	546	1	500	1
15Nov/00	200	100	1	706	3	500	3
15Nov/12	250	299	1	299	1	-500	4
25Nov/00	400	425	1	426	1	200	3
25Nov/12	100	100	1	100	1	200	1
26Nov/00	500	547	1	548	1	100	3
04Dec/12	100	100	1	4567	3	100	1
05Dec/00	1600	1654	1	1655	1	2000	3
05Dec/12	100	100	1	100	1	100	1
15Dec/00	m	m	m	m	m	m	m
15Dec/12	500	100	3	539	1	500	1
16Dec/00	700	794	1	795	1	700	1
24Dec/12	100	100	1	100	1	200	1
25Dec/00	500	554	1	554	1	-500	4
25Dec/12	100	100	1	283	3	300	3

TABLE D4: Analysis Results for Vandenburg AFB, California. Labels as in Table D1.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
10Jan/00	500	511	1	511	1	500	1
10Jan/12	m	m		m		m	
11Jan/00	500	2103	3	545	1	500	1
19Jan/12	m	m		m		m	
20Jan/00	1800	575	3	576	3	600	3
20Jan/12	m	m		m		m	
30Jan/00	800	892	1	290	3	300	3
30Jan/12	m	m		m		m	
31Jan/00	400	587	3	468	1	300	1
08Feb/12	m	m		m		m	
09Feb/00	200	195	1	178	1	200	1
09Feb/12	350	369	1	370	1	400	1
19Feb/00	150	133	1	134	1	300	3
19Feb/12	m	m		m		m	
20Feb/00	1250	1618	3	607	3	1600	3
28Feb/12	100	1927	3	1906	3	100	1
29Feb/00	3800	2487	3	2107	3	500	3
29Feb/12	m	m		m		m	
10Mar/00	450	412	1	413	1	400	1
10Mar/12	m	m		m		m	
11Mar/00	1500	551	3	599	3	400	3
19Mar/12	300	289	1	290	1	300	1
20Mar/00	200	196	1	196	1	200	1
20Mar/12	m	m		m		m	
30Mar/00	400	377	1	363	1	400	1
30Mar/12	m	m		m		m	
31Mar/00	100	677	3	614	3	200	1
08Apr/12	m	m		m		m	
09Apr/00	650	605	1	606	1	600	1
09Apr/12	1000	1029	1	996	1	600	3
19Apr/00	550	561	1	562	1	900	3
19Apr/12	m	m		m		m	
20Apr/00	450	481	1	256	3	700	3
28Apr/12	m	m		m		m	
29Apr/00	150	163	1	155	1	200	1
29Apr/12	m	m		m		m	
09May/00	150	312	3	259	3	300	3
09May/12	m	m		m		m	
10May/00	300	303	1	304	1	300	1
18May/12	m	m		m		m	
19May/00	150	249	1	211	1	200	1
19May/12	m	m		m		m	

TABLE D4: Continued.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
29May/00	600	-500	4	-500	4	-500	4
29May/12	950	951	1	951	1	1000	1
30May/00	750	763	1	761	1	500	3
07Jun/12	m	m		m		m	
08Jun/00	350	347	1	339	1	100	3
08Jun/12	m	m		m		m	
18Jun/00	100	100	1	-500	4	-500	4
18Jun/12	m	m		m		m	
19Jun/00	200	200	1	201	1	300	1
27Jun/12	m	m		m		m	
28Jun/00	500	526	1	526	1	400	1
28Jun/12	m	m		m		m	
08Jul/00	350	345	1	345	1	400	1
08Jul/12	m	m		m		m	
09Jul/00	350	340	1	338	1	400	1
17Jul/12	m	m		m		m	
18Jul/00	450	451	1	452	1	500	1
18Jul/12	m	m		m		m	
28Jul/00	m	m		m		m	
28Jul/12	m	m		m		m	
29Jul/00	m	m		m		m	
06Aug/12	m	m		m		m	
07Aug/00	500	528	1	528	1	500	1
07Aug/12	m	m		m		m	
17Aug/00	m	-500		-500		-500	
17Aug/12	m	m		m		m	
18Aug/00	350	339	1	337	1	400	1
26Aug/12	m	m		m		m	
27Aug/00	150	211	1	212	1	500	3
27Aug/12	m	m		m		m	
06Sep/00	250	256	1	256	1	300	1
06Sep/12	m	m		m		m	
07Sep/00	100	619	3	642	3	100	1
15Sep/12	m	m		m		m	
16Sep/00	250	304	1	-500	4	300	1
16Sep/12	m	m		m		m	
26Sep/00	600	589	1	582	1	300	3
26Sep/12	700	574	3	575	3	300	3
27Sep/00	400	419	1	420	1	400	1
05Oct/12	100	100	1	100	1	100	1
06Oct/00	100	100	1	100	1	100	1
06Oct/12	m	m		m		m	

TABLE D4: Continued.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
16Oct/00	50	73	1	74	1	200	3
16Oct/12	m	m		m		m	
17Oct/00	100	100	1	1242	3	200	1
25Oct/12	m	m		m		m	
26Oct/00	900	935	1	935	1	600	3
26Oct/12	m	m		m		m	
05Nov/00	800	786	1	681	3	800	1
05Nov/12	1000	957	1	957	1	300	3
06Nov/00	300	330	1	343	1	300	1
14Nov/12	m	m		m		m	
15Nov/00	200	236	1	237	1	600	3
15Nov/12	m	m		m		m	
25Nov/00	100	124	1	125	1	200	1
25Nov/12	m	m		m		m	
26Nov/00	200	181	1	181	1	300	1
04Dec/12	300	384	1	353	1	300	1
05Dec/00	150	153	1	153	1	200	1
05Dec/12	m	m		m		m	
15Dec/00	250	284	1	284	1	300	1
15Dec/12	100	2857	3	2903	3	200	1
16Dec/00	100	100	1	100	1	100	1
24Dec/12	m	m		m		m	
25Dec/00	150	671	3	171	1	300	3
25Dec/12	m	m		m		m	

TABLE D5: Analysis Results for Grand Junction, Colorado. Labels as in Table D1.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
10Jan/00	380	381	1	381	1	-500	4
10Jan/12	100	100	1	100	1	100	1
11Jan/00	2730	2773	1	2773	1	1100	3
19Jan/12	100	100	1	100	1	-500	4
20Jan/00	5830	1426	3	700	3	-500	4
20Jan/12	100	2007	3	2008	3	100	1
30Jan/00	330	380	1	381	1	-500	4
30Jan/12	100	2960	3	2961	3	-500	4
31Jan/00	100	100	1	100	1	-500	4
08Feb/12	100	501	3	502	3	100	1
09Feb/00	730	713	1	758	1	600	3
09Feb/12	100	100	1	100	1	-500	4
19Feb/00	6530	6731	1	2838	3	400	3
19Feb/12	100	100	1	100	1	400	3
20Feb/00	1530	3329	3	1804	3	600	3
28Feb/12	2130	2228	1	727	3	100	3
29Feb/00	4130	4130	1	4131	1	2300	3
29Feb/12	3380	1391	3	1317	3	100	3
10Mar/00	1330	1327	1	1370	1	1000	3
10Mar/12	100	100	1	730	3	100	1
11Mar/00	830	2557	3	957	3	400	3
19Mar/12	830	861	1	890	1	100	3
20Mar/00	1430	2081	3	1508	1	700	3
20Mar/12	100	617	3	617	3	100	1
30Mar/00	5580	6542	2	1479	3	2200	3
30Mar/12	1430	120	3	120	3	1100	3
31Mar/00	2630	2753	3	2688	1	400	3
08Apr/12	100	100	1	100	1	100	1
09Apr/00	3030	8702	2	3423	2	-500	4
09Apr/12	100	100	1	100	1	100	1
19Apr/00	100	12519	3	816	3	-500	4
19Apr/12	2730	2740	1	2740	1	1600	3
20Apr/00	3430	3445	1	3402	1	-500	4
28Apr/12	100	4740	3	3436	3	100	1
29Apr/00	4030	5934	2	5870	2	700	3
29Apr/12	100	2640	3	2640	3	100	1
09May/00	5530	5680	1	5576	1	700	3
09May/12	100	7164	3	4156	3	-500	4
10May/00	8830	8891	1	4422	2	1300	3
18May/12	100	3327	3	3344	3	100	1
19May/00	4830	4802	1	4803	1	1300	3
19May/12	100	829	3	874	3	100	1

TABLE D5: Continued.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
29May/00	780	100	3	31295	3	-500	4
29May/12	100	1226	3	1261	3	-500	4
30May/00	4230	4231	1	4261	1	-500	4
07Jun/12	100	1913	3	100	1	-500	4
08Jun/00	1780	11255	3	5291	3	1300	3
08Jun/12	100	100	1	100	1	100	1
18Jun/00	5330	5381	1	5348	1	3600	2
18Jun/12	100	100	1	8890	3	100	1
19Jun/00	3530	8594	2	8412	2	-500	4
27Jun/12	100	3972	3	3927	3	400	3
28Jun/00	380	383	1	417	1	-500	4
28Jun/12	100	4526	3	4526	3	400	3
08Jul/00	5930	5918	1	4708	2	400	3
08Jul/12	100	5202	3	4675	3	100	1
09Jul/00	4080	4126	1	4126	1	400	3
17Jul/12	100	4710	3	100	1	100	1
18Jul/00	230	232	1	194	1	200	1
18Jul/12	100	100	1	100	1	400	3
28Jul/00	4830	4888	1	4888	1	1300	3
28Jul/12	m	-500	m	-500	m	-500	m
29Jul/00	980	1097	3	1097	3	1000	1
06Aug/12	100	5003	3	3382	3	100	1
07Aug/00	3730	8111	2	3923	1	3200	2
07Aug/12	100	5057	3	4962	3	100	1
17Aug/00	3930	3966	1	3937	1	1000	3
17Aug/12	230	966	3	982	3	400	3
18Aug/00	5830	6377	2	4697	2	2300	3
26Aug/12	100	8930	3	8979	3	100	1
27Aug/00	1280	5857	3	3958	3	700	3
27Aug/12	100	2919	3	2920	3	100	1
06Sep/00	100	3013	3	97	1	400	3
06Sep/12	100	2507	3	2508	3	-500	4
07Sep/00	730	4765	3	789	1	700	1
15Sep/12	100	1207	3	1207	3	100	1
16Sep/00	1780	2787	3	2177	3	700	3
16Sep/12	100	3236	3	3237	3	200	1
26Sep/00	3930	4046	1	4047	1	800	3
26Sep/12	100	2441	3	2490	3	100	1
27Sep/00	4880	4817	1	4746	1	-500	4
05Oct/12	100	2877	3	100	1	100	1
06Oct/00	730	2698	3	763	1	600	3
06Oct/12	100	1077	3	100	1	100	1

TABLE D5: Continued.

Date/Time	Obs	PIMIX	Cat	POTEMP	Cat	RICH	Cat
16Oct/00	2980	2995	1	2996	1	400	3
16Oct/12	100	100	1	3506	3	-500	4
17Oct/00	1530	1540	1	1541	1	700	3
25Oct/12	100	1955	3	1730	3	-500	4
26Oct/00	7580	539	3	539	3	100	3
26Oct/12	100	2934	3	1727	3	1100	3
05Nov/00	2130	2103	1	2078	1	400	3
05Nov/12	100	4109	3	2659	3	-500	4
06Nov/00	4580	4559	1	976	3	100	3
14Nov/12	100	100	1	100	1	100	1
15Nov/00	100	4367	3	100	1	100	1
15Nov/12	400	438	1	438	1	500	1
25Nov/00	1580	1991	3	1250	3	200	3
25Nov/12	100	100	1	100	1	100	1
26Nov/00	2030	2093	1	2004	1	-500	4
04Dec/12	100	3180	3	1543	3	-500	4
05Dec/00	1530	1517	1	1517	1	-500	4
05Dec/12	100	1312	3	1313	3	200	1
15Dec/00	3530	3522	1	3522	1	2500	3
15Dec/12	2630	2661	1	2600	1	-500	4
16Dec/00	780	1101	3	1031	3	1500	3
24Dec/12	100	2030	3	2030	3	100	1
25Dec/00	100	100	1	100	1	100	1
25Dec/12	100	100	1	100	1	100	1

This Appendix contains the hand-analyzed PBL heights from the RAMS forecasted soundings used for the Simulation. The three SLAM algorithms' and the TKE algorithm's PBL estimates, and their RMS error categorizations are presented. All dates are in 1996.

TABLE E1: Simulation Results for Key West, Florida. Time is either 00 for 0000 UTC or 12 for 1200 UTC. Anal is the hand-analyzed forecasted PBL heights, while PIMIX, POTEMP, RICH, and TKE are the PBL estimates for the respective algorithms. Cat 1 is a hit, Cat 2 indicates deep convection, Cat 3 is a miss, and Cat 4 is an algorithm failure. Missing data is indicated by m.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
10Jan/00	600	780	3	639	1	200	3	m	
10Jan/12	500	805	3	805	3	600	1	446	1
11Jan/00	600	1013	3	686	1	200	3	642	1
19Jan/12	4500	3770	2	699	3	100	3	m	
20Jan/00	450	591	3	472	1	300	3	446	1
20Jan/12	400	403	1	404	1	300	1	446	1
30Jan/00	1500	3126	3	1100	3	200	3	m	
30Jan/12	1600	3135	3	685	3	300	3	648	3
31Jan/00	1900	3790	3	701	3	300	3	446	3
08Feb/12	1700	2062	3	689	3	100	3	m	
09Feb/00	1600	1718	3	495	3	500	3	446	3
09Feb/12	1600	1695	1	551	3	500	3	100	3
19Feb/00	1300	1077	3	1078	3	100	3	m	
19Feb/12	1000	1032	1	893	3	200	3	100	3
20Feb/00	1200	1007	3	1008	3	700	3	636	3
28Feb/12	750	787	1	788	1	200	3	m	
29Feb/00	700	1040	3	833	3	300	3	636	1
29Feb/12	1000	1025	1	791	3	200	3	100	3
10Mar/00	1600	1048	3	1049	3	900	3	m	
10Mar/12	600	629	1	629	1	400	3	636	1
11Mar/00	2500	1105	3	1105	3	300	3	1463	3
19Mar/12	2500	10025	3	540	3	1200	3	m	
20Mar/00	1000	993	1	878	3	1000	1	636	3
20Mar/12	1600	1121	3	1121	3	300	3	1153	3
30Mar/00	700	8798	3	712	1	100	3	m	
30Mar/12	500	618	3	618	3	200	3	100	3
31Mar/00	400	629	3	478	1	400	1	284	3
08Apr/12	500	7803	3	698	3	200	3	m	
09Apr/00	500	7842	3	712	3	200	3	462	1
09Apr/12	4800	5634	2	704	3	400	3	446	3
19Apr/00	950	993	1	994	1	100	3	m	
19Apr/12	1000	1008	1	1008	1	300	3	870	3

TABLE E1: Continued.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
20Apr/00	1000	997	1	998	1	500	3	863	3
28Apr/12	1900	8818	3	1085	3	200	3	m	
29Apr/00	500	8797	3	681	3	500	1	548	1
29Apr/12	700	1078	3	903	3	900	3	628	1
09May/00	900	2536	3	1083	3	700	3	m	
09May/12	900	10152	3	908	1	400	3	853	1
10May/00	1600	10147	3	871	3	700	3	863	3
18May/12	1100	6651	3	1119	1	600	3	m	
19May/00	700	4641	3	675	1	300	3	636	1
19May/12	5600	4626	2	705	3	700	3	636	3
29May/00	m	m		m		m		m	
29May/12	1200	6617	3	861	3	200	3	661	3
30May/00	900	6617	3	860	1	200	3	494	3
07Jun/12	1700	8797	3	860	3	300	3	m	
08Jun/00	2000	10006	3	1084	3	300	3	863	3
08Jun/12	2400	8782	3	897	3	400	3	863	3
18Jun/00	700	10110	3	1053	3	300	3	m	
18Jun/12	800	8781	3	831	1	200	3	863	1
19Jun/00	700	10128	3	691	1	500	3	634	1
27Jun/12	700	6170	3	815	3	300	3	m	
28Jun/00	10600	11783	2	861	3	500	3	621	3
28Jun/12	11500	11847	2	1140	3	300	3	863	3
08Jul/00	1900	6623	3	693	3	500	3	m	
08Jul/12	2000	11934	3	839	3	300	3	600	3
09Jul/00	2300	10943	3	892	3	400	3	636	3
17Jul/12	1100	11936	3	1150	1	1000	1	m	
18Jul/00	3600	10246	2	838	3	1000	3	863	3
18Jul/12	3000	10936	2	1101	3	500	3	1136	3
28Jul/00	2300	10183	3	1403	3	1200	3	m	
28Jul/12	1000	10192	3	820	3	1000	1	863	3
29Jul/00	900	10219	3	872	1	300	3	863	1
06Aug/12	12300	12799	2	689	3	1200	3	m	
07Aug/00	11500	11937	2	826	3	900	3	921	3
07Aug/12	8500	10191	2	879	3	400	3	863	3
17Aug/00	1100	10180	3	1122	1	400	3	m	
17Aug/12	7500	10200	2	1106	3	600	3	863	3
18Aug/00	7500	10919	2	880	3	400	3	863	3
26Aug/12	12500	12020	2	1121	3	100	3	m	
27Aug/00	12400	11973	2	918	3	300	3	693	3
27Aug/12	12500	11936	2	708	3	500	3	636	3
06Sep/00	1500	10114	3	1034	3	300	3	m	
06Sep/12	700	10143	3	847	3	300	3	636	1
07Sep/00	1200	10143	3	1082	3	100	3	813	3
15Sep/12	6300	6623	2	1414	3	200	3	m	

TABLE E1: Continued.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
16Sep/00	3600	11911	2	722	3	400	3	636	3
16Sep/12	5400	6151	2	683	3	400	3	636	3
26Sep/00	3000	10890	2	1056	3	400	3	m	
26Sep/12	4400	10186	2	1084	3	500	3	1136	3
27Sep/00	3600	3429	1	860	3	400	3	863	3
05Oct/12	13500	11939	2	898	3	100	3	m	
06Oct/00	11700	11849	1	1107	3	300	3	629	3
06Oct/12	11700	6611	2	894	3	400	3	636	3
16Oct/00	5400	8697	2	1070	3	1000	3	m	
16Oct/12	7500	1026	2	893	3	400	3	1136	3
17Oct/00	7500	10099	2	904	3	700	3	863	3
25Oct/12	1900	1962	1	843	3	900	3	m	
26Oct/00	2300	1774	3	879	3	900	3	863	3
26Oct/12	1900	1719	3	1124	3	900	3	863	3
05Nov/00	4400	11824	2	1123	3	900	3	m	
05Nov/12	4400	11873	2	877	3	700	3	636	3
06Nov/00	3600	11845	2	909	3	400	3	636	3
14Nov/12	800	1068	3	810	1	1000	3	m	
15Nov/00	4500	7876	2	1106	3	1000	3	863	3
15Nov/12	4600	1091	3	695	3	800	3	735	3
25Nov/00	1600	1657	1	1581	1	1200	3	m	
25Nov/12	1500	1773	3	859	3	700	3	629	3
26Nov/00	2900	6126	3	893	3	500	3	441	3
04Dec/12	1200	1079	3	687	3	400	3	m	
05Dec/00	1600	1092	3	541	3	500	3	446	3
05Dec/12	1600	1772	3	1119	3	400	3	814	3
15Dec/00	800	1748	3	879	1	100	3	m	
15Dec/12	100	1077	3	431	3	400	3	100	1
16Dec/00	1000	1334	3	707	3	500	3	636	3
24Dec/12	1200	2478	3	699	3	200	3	m	
25Dec/00	2300	2040	3	540	3	200	3	446	3
25Dec/12	100	1091	3	566	3	400	3	100	1

TABLE E2: Simulation Results for Lake Charles, Louisiana. Labels as in Table E1.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
10Jan/00	1200	997	3	714	3	900	3	m	m
10Jan/12	100	100	1	100	1	100	1	100	1
11Jan/00	100	1025	3	420	3	300	3	100	1
19Jan/12	600	740	3	666	1	900	3	m	m
20Jan/00	800	739	1	667	3	100	3	462	3
20Jan/12	100	100	1	299	3	300	3	100	1
30Jan/00	800	1104	3	891	1	100	3	m	m
30Jan/12	400	618	3	477	1	600	3	446	1
31Jan/00	1600	1326	3	568	3	600	3	342	3
08Feb/12	100	100	1	100	1	100	1	m	m
09Feb/00	100	100	1	100	1	300	3	216	3
09Feb/12	100	100	1	100	1	300	3	100	1
19Feb/00	2400	1103	3	890	3	1300	3	m	m
19Feb/12	100	628	3	226	3	900	3	100	1
20Feb/00	300	441	3	332	1	300	1	291	1
28Feb/12	700	591	3	511	3	100	3	m	m
29Feb/00	700	731	1	732	1	700	1	863	3
29Feb/12	400	562	3	467	1	400	1	446	1
10Mar/00	1100	1284	3	1284	3	1200	1	m	m
10Mar/12	100	100	1	734	3	100	1	100	1
11Mar/00	1300	1417	3	1418	3	400	3	1463	3
19Mar/12	400	1118	3	714	3	-500	4	m	m
20Mar/00	3000	3197	1	2624	3	-500	4	1855	3
20Mar/12	800	1434	3	928	3	300	3	100	3
30Mar/00	750	1048	3	884	3	200	3	m	m
30Mar/12	100	1007	3	100	1	300	3	100	1
31Mar/00	600	8883	3	655	1	400	3	574	1
08Apr/12	100	100	1	100	1	100	1	m	m
09Apr/00	400	1078	3	562	3	300	1	735	3
09Apr/12	100	100	1	100	1	100	1	100	1
19Apr/00	1200	1280	1	728	3	700	3	m	m
19Apr/12	400	584	3	490	1	600	3	650	3
20Apr/00	600	629	1	629	1	600	1	635	1
28Apr/12	500	584	1	584	1	1000	3	m	m
29Apr/00	600	1019	3	652	1	800	3	788	3
29Apr/12	10400	1079	3	540	3	1200	3	100	3
09May/00	1700	2084	3	921	3	800	3	m	m
09May/12	1200	8816	3	876	3	600	3	415	3
10May/00	800	10081	3	859	1	700	1	962	3
18May/12	700	768	1	402	3	100	3	m	m
19May/00	700	8778	3	916	3	400	3	885	3
19May/12	1000	1067	1	900	1	900	1	100	3

TABLE E2: Continued.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
29May/00	700	11905	3	694	1	300	3	m	m
29May/12	700	788	1	662	1	400	3	654	1
30May/00	600	600	1	600	1	500	1	653	1
07Jun/12	1000	1078	1	902	1	100	3	m	m
08Jun/00	700	8800	3	717	1	800	1	2350	3
08Jun/12	300	8817	3	704	3	300	1	289	1
18Jun/00	700	10940	3	340	3	100	3	m	m
18Jun/12	900	11795	3	712	3	300	3	192	3
19Jun/00	600	11797	3	698	1	800	3	654	1
27Jun/12	400	795	3	431	1	200	3	m	m
28Jun/00	1600	8678	3	1681	1	800	3	1837	3
28Jun/12	500	7915	3	725	3	500	1	446	1
08Jul/00	800	6585	3	386	3	100	3	m	m
08Jul/12	750	1079	3	903	3	700	1	1013	3
09Jul/00	800	10137	3	836	1	1300	3	1012	3
17Jul/12	6200	6215	1	521	3	100	3	m	m
18Jul/00	1100	10913	3	1106	1	400	3	1272	3
18Jul/12	13300	10915	2	543	3	400	3	446	3
28Jul/00	1400	4631	3	1392	1	400	3	m	m
28Jul/12	400	10938	3	898	3	400	1	446	1
29Jul/00	2000	11745	3	819	3	500	3	1046	3
06Aug/12	800	11823	3	398	3	100	3	m	m
07Aug/00	1350	11847	3	1086	3	700	3	1257	1
07Aug/12	500	847	3	728	3	400	1	446	1
17Aug/00	4400	3787	2	1074	3	200	3	m	m
17Aug/12	3000	3795	2	436	3	200	3	100	3
18Aug/00	3000	10174	2	1121	3	1200	3	1048	3
26Aug/12	400	804	3	710	3	200	3	m	m
27Aug/00	4600	11932	2	708	3	800	3	712	3
27Aug/12	7700	11896	2	710	3	500	3	340	3
06Sep/00	4400	4630	1	2147	3	100	3	m	m
06Sep/12	9400	10053	2	705	3	200	3	100	3
07Sep/00	4500	10045	2	676	3	800	3	965	3
15Sep/12	950	1057	3	425	3	1000	1	m	m
16Sep/00	11500	10888	2	893	3	900	3	863	3
16Sep/12	600	3786	3	699	1	900	3	636	1
26Sep/00	2400	11901	3	1091	3	100	3	m	m
26Sep/12	11600	11783	1	532	3	900	3	386	3
27Sep/00	9600	11906	2	686	3	800	3	661	3
05Oct/12	700	796	1	662	1	1000	3	m	m
06Oct/00	500	608	3	497	1	600	1	574	1
06Oct/12	500	557	1	452	1	500	1	446	1

TABLE E2: Continued.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
16Oct/00	1200	1362	3	1091	3	100	3	m	m
16Oct/12	100	100	1	100	1	400	3	100	1
17Oct/00	750	1090	3	903	3	500	3	719	1
25Oct/12	500	599	1	484	1	1200	3	m	m
26Oct/00	750	618	3	618	3	600	3	363	3
26Oct/12	700	738	1	653	1	400	3	863	3
05Nov/00	1600	1651	1	691	3	100	3	m	m
05Nov/12	1900	100	3	100	3	300	3	100	3
06Nov/00	1900	1771	3	743	3	400	3	443	3
14Nov/12	1000	608	3	100	3	100	3	m	m
15Nov/00	1000	1777	3	910	1	400	3	438	3
15Nov/12	100	100	1	100	1	300	3	100	1
25Nov/00	800	1078	3	444	3	1600	3	m	m
25Nov/12	700	997	3	651	1	500	3	638	1
26Nov/00	900	945	1	945	1	900	1	863	1
04Dec/12	100	608	3	385	3	400	3	m	m
05Dec/00	500	617	3	618	3	400	1	458	1
05Dec/12	100	100	1	100	1	300	3	100	1
15Dec/00	700	795	1	796	1	400	3	m	m
15Dec/12	100	100	1	100	1	300	3	100	1
16Dec/00	7600	1326	3	1119	3	400	3	1714	3
24Dec/12	400	433	1	433	1	400	1	m	m
25Dec/00	700	732	1	733	1	400	3	636	1
25Dec/12	100	100	1	100	1	300	3	100	1

TABLE E3: Simulation Results for North Platte, Nebraska. Labels as in Table E1.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
10Jan/00	135	650	3	100	1	200	1	m	m
10Jan/12	100	579	3	579	3	600	3	100	1
11Jan/00	2435	578	3	578	3	600	3	824	3
19Jan/12	100	222	3	555	3	100	1	m	m
20Jan/00	335	327	1	488	3	400	1	276	1
20Jan/12	100	100	1	508	3	100	1	100	1
30Jan/00	100	562	3	562	3	100	1	m	m
30Jan/12	335	348	1	561	3	400	1	438	3
31Jan/00	485	571	1	571	1	600	3	548	1
08Feb/12	100	597	3	597	3	700	3	m	m
09Feb/00	485	586	3	586	3	600	3	427	1
09Feb/12	100	100	1	580	3	400	3	100	1
19Feb/00	2835	489	3	490	3	600	3	m	m
19Feb/12	100	482	3	483	3	300	3	100	1
20Feb/00	535	461	1	462	1	600	1	623	1
28Feb/12	335	100	3	100	3	100	3	m	m
29Feb/00	735	635	1	100	3	800	1	839	1
29Feb/12	100	100	1	100	1	100	1	100	1
10Mar/00	1835	669	3	100	3	800	3	m	m
10Mar/12	100	100	1	100	1	300	3	100	1
11Mar/00	535	512	1	100	3	800	3	612	1
19Mar/12	635	2082	3	707	1	700	1	m	m
20Mar/00	1235	623	3	100	3	800	3	1676	3
20Mar/12	100	100	1	100	1	300	3	100	1
30Mar/00	1135	736	3	405	3	100	3	m	m
30Mar/12	535	100	3	100	3	300	3	100	3
31Mar/00	735	998	3	838	3	900	3	999	3
08Apr/12	100	100	1	100	1	100	1	m	m
09Apr/00	2235	9487	3	2494	3	2900	3	1774	3
09Apr/12	100	100	1	100	1	100	1	456	3
19Apr/00	1735	7447	3	7280	3	100	3	m	m
19Apr/12	100	4595	3	869	3	400	3	100	1
20Apr/00	8135	3828	2	1696	3	1200	3	1800	3
28Apr/12	535	593	1	593	1	100	3	m	m
29Apr/00	2435	626	3	100	3	800	3	1117	3
29Apr/12	100	651	3	100	1	300	3	100	1
09May/00	835	801	1	422	3	100	3	m	m
09May/12	1035	755	3	100	3	300	3	100	3
10May/00	735	771	1	756	1	1500	3	1085	3
18May/12	100	100	1	100	1	100	1	m	m
19May/00	735	9468	3	758	1	1000	3	323	3
19May/12	100	100	1	100	1	300	3	100	1

TABLE E3: Continued.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
29May/00	735	1006	3	876	3	200	3	m	m
29May/12	100	100	1	100	1	100	1	100	1
30May/00	1235	1273	1	1274	1	1500	3	1405	3
07Jun/12	635	1027	3	868	3	1200	3	m	m
08Jun/00	1485	1554	1	1555	1	1000	3	1661	3
08Jun/12	100	100	1	100	1	100	1	100	1
18Jun/00	885	8401	3	1065	3	700	3	m	m
18Jun/12	100	559	3	100	1	300	3	100	1
19Jun/00	1535	8450	3	1668	3	800	3	1737	3
27Jun/12	385	585	3	375	1	900	3	m	m
28Jun/00	1335	10727	3	1343	1	1100	3	1774	3
28Jun/12	485	607	3	500	1	500	1	608	3
08Jul/00			m		m		m	m	m
08Jul/12			m		m		m		m
09Jul/00			m		m		m		m
17Jul/12	285	547	3	100	3	900	3	m	m
18Jul/00	1635	10704	3	3645	3	900	3	2225	3
18Jul/12	235	425	3	321	1	300	1	456	3
28Jul/00			m		m		m	m	m
28Jul/12			m		m		m		m
29Jul/00			m		m		m		m
06Aug/12	100	364	3	100	1	100	1	m	m
07Aug/00	1535	8388	3	1689	3	1900	3	2225	3
07Aug/12	235	966	3	345	3	700	3	145	1
17Aug/00	1435	9427	3	1344	1	500	3	m	m
17Aug/12	135	575	3	100	1	200	1	100	1
18Aug/00	1235	1274	1	1274	1	700	3	1646	3
26Aug/12	100	100	1	100	1	100	1	m	m
27Aug/00	1335	7421	3	1318	1	1100	3	1774	3
27Aug/12	735	824	1	669	1	300	3	100	3
06Sep/00	1535	9383	3	1697	3	1000	3	m	m
06Sep/12	100	100	1	100	1	300	3	266	3
07Sep/00	10135	9513	2	1065	3	900	3	1086	3
15Sep/12	235	566	3	100	3	100	3	m	m
16Sep/00	385	566	3	454	1	300	1	437	1
16Sep/12	185	256	1	256	1	300	3	277	1
26Sep/00	635	726	1	395	3	200	3	m	m
26Sep/12	535	789	3	543	1	300	3	282	3
27Sep/00	6235	5598	2	1364	3	1200	3	1399	3
05Oct/12	385	547	3	459	1	500	3	m	m
06Oct/00	935	9543	3	1047	3	900	1	1085	3
06Oct/12	100	100	1	100	1	200	1	100	1

TABLE E3: Continued.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
16Oct/00	100	977	3	553	3	100	1	m	m
16Oct/12	100	100	1	100	1	200	1	100	1
17Oct/00	685	789	3	789	3	500	3	825	3
25Oct/12	100	100	1	100	1	100	1	m	m
26Oct/00	735	990	3	827	1	700	1	755	1
26Oct/12	100	1064	3	891	3	400	3	100	1
05Nov/00	100	1064	3	437	3	1100	3	m	m
05Nov/12	100	100	1	100	1	100	1	100	1
06Nov/00	535	789	3	656	3	100	3	452	1
14Nov/12	485	532	1	476	1	700	3	m	m
15Nov/00	485	538	1	456	1	700	3	620	3
15Nov/12	100	100	1	100	1	900	3	100	1
25Nov/00	335	415	1	415	1	100	3	m	m
25Nov/12	100	100	1	100	1	100	1	100	1
26Nov/00	485	415	1	416	1	100	3	282	3
04Dec/12	100	100	1	100	1	100	1	m	m
05Dec/00	100	3848	3	651	3	500	3	276	3
05Dec/12	100	100	1	100	1	300	3	100	1
15Dec/00	685	813	3	530	3	900	3	m	m
15Dec/12	100	100	1	100	1	300	3	100	1
16Dec/00	100	100	1	558	3	700	3	100	1
24Dec/12	100	100	1	100	1	100	1	m	m
25Dec/00	235	368	3	285	1	-500	4	100	3
25Dec/12	100	100	1	100	1	100	1	100	1

TABLE E4: Simulation Results for Vandenburg AFB, California. Labels as in Table E1.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
10Jan/00	550	570	1	570	1	100	3	m	m
10Jan/12	100	100	1	100	1	300	3	100	1
11Jan/00	100	2064	3	481	3	300	3	452	3
19Jan/12	1200	1100	1	350	3	100	3	m	m
20Jan/00	1600	1699	1	1112	3	500	3	860	3
20Jan/12	100	100	1	100	1	300	3	100	1
30Jan/00	750	1021	3	769	1	200	3	m	m
30Jan/12	100	100	1	100	1	300	3	100	1
31Jan/00	550	1116	3	652	3	600	1	873	3
08Feb/12	100	100	1	100	1	100	1	m	m
09Feb/00	300	415	3	332	1	300	1	443	3
09Feb/12	100	100	1	100	1	300	3	100	1
19Feb/00	550	4671	3	518	1	100	3	m	m
19Feb/12	700	1102	3	695	1	400	3	100	3
20Feb/00	10350	3239	2	304	3	400	3	387	3
28Feb/12	100	100	1	100	1	100	1	m	m
29Feb/00	3050	2608	3	1713	3	500	3	1031	3
29Feb/12	100	100	1	-500	4	800	3	100	1
10Mar/00	450	1074	3	712	3	100	3	m	m
10Mar/12	100	100	1	100	1	200	1	100	1
11Mar/00	550	1101	3	724	3	400	3	633	1
19Mar/12	350	100	3	100	3	100	3	m	m
20Mar/00	350	397	1	326	1	200	3	443	1
20Mar/12	100	100	1	100	1	100	1	100	1
30Mar/00	350	1029	3	705	3	100	3	m	m
30Mar/12	100	100	1	100	1	300	3	100	1
31Mar/00	400	597	3	471	1	500	1	633	3
08Apr/12	100	397	3	239	3	100	1	m	m
09Apr/00	450	597	3	471	1	200	3	631	3
09Apr/12	100	100	1	100	1	100	1	100	1
19Apr/00	750	4710	3	853	3	700	1	m	m
19Apr/12	100	100	1	100	1	400	3	100	1
20Apr/00	550	3308	3	698	3	400	3	860	3
28Apr/12	100	100	1	100	1	100	1	m	m
29Apr/00	250	384	3	295	1	200	1	470	3
29Apr/12	100	100	1	100	1	100	1	100	1
09May/00	550	1036	3	669	3	100	3	m	m
09May/12	100	100	1	100	1	400	3	100	1
10May/00	300	431	3	338	1	700	3	129	3
18May/12	650	985	3	426	3	100	3	m	m
19May/00	650	1054	3	881	3	400	3	857	3
19May/12	250	1028	3	100	3	600	3	100	3

TABLE E4: Continued.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
29May/00	100	100	1	100	1	100	1	m	m
29May/12	950	100	3	100	3	400	3	100	3
30May/00	550	978	3	531	1	300	3	630	1
07Jun/12	100	392	3	100	1	100	1	m	m
08Jun/00	400	380	1	339	1	500	1	644	3
08Jun/12	100	100	1	100	1	200	1	100	1
18Jun/00	350	440	1	351	1	100	3	m	m
18Jun/12	100	100	1	100	1	400	3	100	1
19Jun/00	250	280	1	281	1	300	1	530	3
27Jun/12	550	615	1	398	3	100	3	m	m
28Jun/00	650	3290	3	700	1	500	3	872	3
28Jun/12	100	100	1	100	1	400	3	100	1
08Jul/00	m	m	m	m	m	m	m	m	m
08Jul/12	m	m	m	m	m	m	m	m	m
09Jul/00	m	m	m	m	m	m	m	m	m
17Jul/12	700	559	3	480	3	100	3	m	m
18Jul/00	450	559	3	450	1	700	3	633	3
18Jul/12	100	273	3	100	1	300	3	100	1
28Jul/00	450	402	1	403	1	400	1	m	m
28Jul/12	350	100	3	100	3	100	3	100	3
29Jul/00	400	380	1	380	1	700	3	644	3
06Aug/12	650	575	1	503	3	200	3	m	m
07Aug/00	450	537	1	461	1	700	3	634	3
07Aug/12	100	100	1	100	1	300	3	100	1
17Aug/00	100	392	3	100	1	100	1	m	m
17Aug/12	100	100	1	100	1	300	3	100	1
18Aug/00	350	376	1	336	1	400	1	522	3
26Aug/12	100	423	3	269	3	100	1	m	m
27Aug/00	450	440	1	441	1	300	3	634	3
27Aug/12	100	100	1	100	1	400	3	100	1
06Sep/00	350	606	3	483	3	100	3	m	m
06Sep/12	100	100	1	100	1	300	3	100	1
07Sep/00	350	440	1	361	1	800	3	530	3
15Sep/12	650	589	1	393	3	100	3	m	m
16Sep/00	550	1015	3	565	1	400	3	634	1
16Sep/12	200	251	1	251	1	500	3	165	1
26Sep/00	550	534	1	534	1	200	3	m	m
26Sep/12	100	100	1	100	1	300	3	100	1
27Sep/00	450	415	1	416	1	500	1	656	3
05Oct/12	100	100	1	100	1	100	1	m	m
06Oct/00	350	388	1	323	1	100	3	376	1
06Oct/12	100	100	1	100	1	100	1	100	1

TABLE E4: Continued.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
16Oct/00	300	409	3	256	1	200	1	m	m
16Oct/12	100	100	1	100	1	400	3	100	1
17Oct/00	300	431	3	309	1	500	3	454	3
25Oct/12	1050	1009	1	442	3	100	3	m	m
26Oct/00	950	2127	3	1079	3	700	3	1131	3
26Oct/12	750	1722	3	723	1	800	1	645	3
05Nov/00	750	1009	3	537	3	300	3	m	m
05Nov/12	100	100	1	531	3	400	3	100	1
06Nov/00	100	1100	3	888	3	300	3	100	1
14Nov/12	400	582	3	450	1	400	1	m	m
15Nov/00	100	1036	3	332	3	300	3	209	3
15Nov/12	500	431	1	431	1	600	1	447	1
25Nov/00	300	589	3	333	1	100	3	m	m
25Nov/12	100	100	1	100	1	100	1	100	1
26Nov/00	100	1101	3	100	1	300	3	100	1
04Dec/12	350	408	1	337	1	200	3	m	m
05Dec/00	400	1101	3	704	3	300	1	456	1
05Dec/12	100	100	1	100	1	200	1	100	1
15Dec/00	400	1075	3	531	3	400	1	m	m
15Dec/12	100	100	1	349	3	400	3	100	1
16Dec/00	400	415	1	367	1	100	3	288	3
24Dec/12	100	100	1	100	1	100	1	m	m
25Dec/00	300	606	3	361	1	300	1	210	1
25Dec/12	100	100	1	100	1	100	1	100	1

TABLE E5: Simulation Results for Grand Junction, Colorado. Labels as in Table E1.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
10Jan/00	256	405	3	323	1	100	3	m	m
10Jan/12	100	100	1	437	3	200	1	100	1
11Jan/00	356	793	3	423	1	100	3	512	3
19Jan/12	100	413	3	336	3	-500	4	m	m
20Jan/00	656	792	3	411	3	300	3	100	3
20Jan/12	356	100	3	380	1	1500	3	100	3
30Jan/00	356	767	3	509	3	100	3	m	m
30Jan/12	256	2020	3	407	3	200	1	100	3
31Jan/00	406	793	3	525	3	200	3	139	3
08Feb/12	100	100	1	100	1	100	1	m	m
09Feb/00	456	758	3	638	3	300	3	497	1
09Feb/12	100	100	1	100	1	200	1	100	1
19Feb/00	2756	6241	3	2973	3	1500	3	m	m
19Feb/12	100	100	1	100	1	100	1	100	1
20Feb/00	556	3668	3	679	3	300	3	2285	3
28Feb/12	556	779	3	617	1	100	3	m	m
29Feb/00	1956	2592	3	2002	1	700	3	2448	3
29Feb/12	2956	2949	1	231	3	200	3	100	3
10Mar/00	956	1266	3	1061	1	500	3	m	m
10Mar/12	100	100	1	100	1	200	1	100	1
11Mar/00	556	726	3	610	1	500	1	618	1
19Mar/12	256	531	3	341	1	200	1	m	m
20Mar/00	856	1636	3	864	1	500	3	812	1
20Mar/12	100	100	1	100	1	200	1	100	1
30Mar/00	5256	6313	2	1346	3	900	3	m	m
30Mar/12	2856	2446	3	217	3	300	3	100	3
31Mar/00	1656	4642	3	2435	3	400	3	2000	3
08Apr/12	100	526	3	328	3	100	1	m	m
09Apr/00	756	8640	3	3601	3	600	3	775	1
09Apr/12	100	726	3	100	1	200	1	100	1
19Apr/00	5156	5432	2	2433	3	1600	3	m	m
19Apr/12	2856	3005	3	1082	3	500	3	1360	3
20Apr/00	2356	3066	3	2913	3	500	3	564	3
28Apr/12	100	1041	3	703	3	1200	3	m	m
29Apr/00	2456	3801	3	3605	3	-500	4	3315	3
29Apr/12	100	100	1	554	3	300	3	100	1
09May/00	2856	8600	3	8958	3	-500	4	m	m
09May/12	100	6424	3	701	3	200	1	100	1
10May/00	7856	7435	2	4561	2	2200	3	4265	3
18May/12	100	551	3	356	3	2800	3	m	m
19May/00	2356	10063	3	2936	3	-500	4	3702	3
19May/12	100	5287	3	2941	3	-500	4	100	1

TABLE E5: Continued.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
29May/00	556	793	3	793	3	300	3	m	m
29May/12	756	1025	3	659	1	100	3	100	3
30May/00	2356	6397	3	6148	3	2300	1	3314	3
07Jun/12	100	396	3	264	3	100	1	m	m
08Jun/00	1356	9329	3	2028	3	400	3	1084	3
08Jun/12	100	749	3	100	1	200	1	100	1
18Jun/00	4956	6504	2	5209	2	-500	4	m	m
18Jun/12	100	7314	3	240	3	300	3	100	1
19Jun/00	2956	8614	3	8430	3	500	3	2094	3
27Jun/12	256	560	3	340	1	100	3	m	m
28Jun/00	4356	6391	2	3576	2	2200	3	3319	3
28Jun/12	356	579	3	487	3	500	3	100	3
08Jul/00			m		m		m	m	m
08Jul/12			m		m		m		m
09Jul/00			m		m		m		m
17Jul/12	256	578	3	373	3	100	3	m	m
18Jul/00	2856	9189	3	3589	3	600	3	1690	3
18Jul/12	456	749	3	657	3	400	1	100	3
28Jul/00	3456	9197	2	5222	2	100	3	m	m
28Jul/12	100	9199	3	524	3	900	3	100	1
29Jul/00	656	9187	3	649	1	500	3	1412	3
06Aug/12	100	559	3	100	1	100	1	m	m
07Aug/00	2256	8519	3	7991	3	1400	3	1936	3
07Aug/12	100	7273	3	547	3	100	1	100	1
17Aug/00	3506	9164	2	3576	1	1800	3	m	m
17Aug/12	100	9048	3	548	3	100	1	100	1
18Aug/00	5156	9133	2	5192	1	100	3	1983	3
26Aug/12	306	741	3	503	3	100	3	m	m
27Aug/00	5556	8124	2	3554	2	100	3	742	3
27Aug/12	256	781	3	524	3	300	1	100	3
06Sep/00	100	100	1	100	1	100	1	m	m
06Sep/12	100	5288	3	239	3	100	1	100	1
07Sep/00	756	5278	3	2937	3	700	1	1563	3
15Sep/12	100	100	1	100	1	100	1	m	m
16Sep/00	756	8606	3	795	1	500	3	1104	3
16Sep/12	100	100	1	100	1	300	3	100	1
26Sep/00	2856	6318	3	3542	3	1200	3	m	m
26Sep/12	556	4481	3	2435	3	100	3	178	3
27Sep/00	2756	3697	3	3543	3	1500	3	2368	3
05Oct/12	100	100	1	100	1	200	1	m	m
06Oct/00	556	8643	3	647	1	300	3	607	1
06Oct/12	100	100	1	100	1	200	1	100	1

TABLE E5: Continued.

Date/Time	Anal	PIMIX	Cat	POTEMP	Cat	RICH	Cat	TKE	Cat
16Oct/00	2356	8658	3	2951	3	3400	3	m	m
16Oct/12	100	4600	3	8948	3	200	1	100	1
17Oct/00	506	4524	3	500	1	500	1	397	3
25Oct/12	256	768	3	517	3	900	3	m	m
26Oct/00	356	6302	3	512	3	200	3	2141	3
26Oct/12	4356	4636	2	523	3	400	3	667	3
05Nov/00	256	1900	3	413	3	200	1	m	m
05Nov/12	100	100	1	535	3	300	3	100	1
06Nov/00	4156	3682	2	413	3	900	3	352	3
14Nov/12	100	100	1	100	1	100	1	m	m
15Nov/00	456	568	3	480	1	300	3	336	3
15Nov/12	556	1340	3	820	3	200	3	1529	3
25Nov/00	356	1026	3	855	3	200	3	m	m
25Nov/12	100	100	1	323	3	100	1	100	1
26Nov/00	406	6533	3	553	3	100	3	512	3
04Dec/12	100	100	1	100	1	100	1	m	m
05Dec/00	456	1041	3	639	3	200	3	508	1
05Dec/12	100	127	1	128	1	300	3	100	1
15Dec/00	2256	3678	3	3605	3	700	3	m	m
15Dec/12	100	2102	3	539	3	400	3	100	1
16Dec/00	456	1027	3	856	3	100	3	502	1
24Dec/12	100	100	1	100	1	300	3	m	m
25Dec/00	406	780	3	510	3	200	3	575	3
25Dec/12	100	100	1	100	1	200	1	100	1

Appendix F: Verification Results

This Appendix contains the categories for the Verification. All dates are in 1996. The 00 hour forecasts were not verified.

TABLE F1: Verification Category Results for Key West, Florida. Anal is the category for the forecasted hand analysis. PIMIX, POTEMP, RICH, and TKE are the categories for the respective algorithm output. Time is 00 for 0000 UTC or 12 for 1200 UTC. Missing data denoted by m.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
10Jan/00	m	m	m	m	m
10Jan/12	3	1	1	3	3
11Jan/00	1	3	1	3	1
19Jan/12	m	m	m	m	m
20Jan/00	1	3	1	1	1
20Jan/12	1	1	1	1	1
30Jan/00	m	m	m	m	m
30Jan/12	1	3	3	3	3
31Jan/00	3	3	3	3	3
08Feb/12	m	m	m	m	m
09Feb/00	1	3	3	3	3
09Feb/12	3	3	3	3	1
19Feb/00	m	m	m	m	m
19Feb/12	1	1	3	3	3
20Feb/00	1	3	3	3	3
28Feb/12	m	m	m	m	m
29Feb/00	3	3	3	1	3
29Feb/12	3	3	3	3	3
10Mar/00	m	m	m	m	m
10Mar/12	1	1	1	3	1
11Mar/00	3	3	3	3	3
19Mar/12	m	m	m	m	m
20Mar/00	1	3	3	1	3
20Mar/12	1	3	3	3	3
30Mar/00	m	m	m	m	m
30Mar/12	1	1	1	3	3
31Mar/00	1	3	3	1	1
08Apr/12	m	m	m	m	m
09Apr/00	3	3	3	1	3
09Apr/12	2	2	3	3	3
19Apr/00	m	m	m	m	m
19Apr/12	1	1	1	3	1
20Apr/00	1	1	1	3	3
28Apr/12	m	m	m	m	m

TABLE F1: Continued.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
29Apr/00	3	2	3	3	3
29Apr/12	1	3	3	1	3
09May/00	m	m	m	m	m
09May/12	3	3	3	3	3
10May/00	3	2	3	3	3
18May/12	m	m	m	m	m
19May/00	3	3	3	3	3
19May/12	1	2	3	3	3
29May/00	m	m	m	m	m
29May/12	3	3	3	3	3
30May/00	1	3	1	3	3
07Jun/12	m	m	m	m	m
08Jun/00	3	3	3	3	3
08Jun/12	3	3	3	3	3
18Jun/00	m	m	m	m	m
18Jun/12	3	2	3	3	3
19Jun/00	3	2	3	3	3
27Jun/12	m	m	m	m	m
28Jun/00	2	2	3	3	3
28Jun/12	3	3	1	3	3
08Jul/00	m	m	m	m	m
08Jul/12	m	m	m	m	m
09Jul/00	3	3	3	3	3
17Jul/12	m	m	m	m	m
18Jul/00	2	2	3	3	3
18Jul/12	3	3	3	3	3
28Jul/00	m	m	m	m	m
28Jul/12	3	2	3	3	3
29Jul/00	3	2	3	3	3
06Aug/12	m	m	m	m	m
07Aug/00	2	2	3	3	3
07Aug/12	2	2	3	3	3
17Aug/00	m	m	m	m	m
17Aug/12	1	2	3	3	3
18Aug/00	2	2	3	3	3
26Aug/12	m	m	m	m	m
27Aug/00	2	2	3	3	3
27Aug/12	1	2	3	3	3
06Sep/00	m	m	m	m	m
06Sep/12	1	3	1	3	3
07Sep/00	3	3	1	3	3
15Sep/12	m	m	m	m	m
16Sep/00	2	2	3	3	3
16Sep/12	2	2	3	3	3

TABLE F1: Continued.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
26Sep/00	m	m	m	m	m
26Sep/12	2	2	3	3	3
27Sep/00	2	2	3	3	3
05Oct/12	m	m	m	m	m
06Oct/00	2	2	3	3	3
06Oct/12	2	2	3	3	3
16Oct/00	m	m	m	m	m
16Oct/12	2	3	3	3	3
17Oct/00	3	2	3	3	3
25Oct/12	m	m	m	m	m
26Oct/00	3	1	3	3	3
26Oct/12	3	3	3	3	3
05Nov/00	m	m	m	m	m
05Nov/12	2	2	3	3	3
06Nov/00	2	2	3	3	3
14Nov/12	m	m	m	m	m
15Nov/00	2	2	3	3	3
15Nov/12	3	3	3	3	3
25Nov/00	m	m	m	m	m
25Nov/12	3	3	1	1	3
26Nov/00	3	3	1	3	3
04Dec/12	m	m	m	m	m
05Dec/00	1	3	3	3	3
05Dec/12	1	3	3	3	3
15Dec/00	m	m	m	m	m
15Dec/12	3	1	3	3	3
16Dec/00	3	1	3	3	3
24Dec/12	m	m	m	m	m
25Dec/00	3	3	3	3	3
25Dec/12	1	3	3	3	1

TABLE F2: Verification Category Results for Lake Charles, Louisiana. Labels as in Table F1.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
10Jan/00	m	m	m	m	m
10Jan/12	3	3	3	3	3
11Jan/00	3	3	3	3	3
19Jan/12	m	m	m	m	m
20Jan/00	1	3	3	3	3
20Jan/12	1	1	3	3	1
30Jan/00	m	m	m	m	m
30Jan/12	3	3	3	3	3
31Jan/00	3	3	3	3	3
08Feb/12	m	m	m	m	m
09Feb/00	m	m	m	m	m
09Feb/12	1	1	1	3	1
19Feb/00	m	m	m	m	m
19Feb/12	3	3	3	3	3
20Feb/00	3	3	3	3	3
28Feb/12	m	m	m	m	m
29Feb/00	3	3	3	3	3
29Feb/12	3	1	3	3	3
10Mar/00	m	m	m	m	m
10Mar/12	3	3	3	3	3
11Mar/00	3	3	3	3	3
19Mar/12	m	m	m	m	m
20Mar/00	1	1	3	4	3
20Mar/12	3	3	3	3	3
30Mar/00	m	m	m	m	m
30Mar/12	1	3	1	1	1
31Mar/00	3	3	3	3	3
08Apr/12	m	m	m	m	m
09Apr/00	1	3	3	1	3
09Apr/12	1	1	1	1	1
19Apr/00	m	m	m	m	m
19Apr/12	3	3	3	3	3
20Apr/00	3	3	3	3	3
28Apr/12	m	m	m	m	m
29Apr/00	3	3	3	1	1
29Apr/12	2	3	3	3	3
09May/00	m	m	m	m	m
09May/12	3	3	3	3	3
10May/00	3	3	3	1	3
18May/12	m	m	m	m	m
19May/00	3	3	3	3	3
19May/12	1	1	1	1	3

TABLE F2: Continued.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
29May/00	m	m	m	m	m
29May/12	1	1	1	3	1
30May/00	1	1	1	1	3
07Jun/12	m	m	m	m	m
08Jun/00	3	2	3	3	3
08Jun/12	3	3	3	3	3
18Jun/00	m	m	m	m	m
18Jun/12	1	3	3	3	3
19Jun/00	3	2	3	3	3
27Jun/12	m	m	m	m	m
28Jun/00	3	1	3	3	3
28Jun/12	3	2	3	3	3
08Jul/00	m	m	m	m	m
08Jul/12	m	m	m	m	m
09Jul/00	3	3	3	3	3
17Jul/12	m	m	m	m	m
18Jul/00	3	3	3	3	3
18Jul/12	1	2	3	3	3
28Jul/00	m	m	m	m	m
28Jul/12	3	3	3	3	3
29Jul/00	3	3	3	3	3
06Aug/12	m	m	m	m	m
07Aug/00	3	2	3	3	3
07Aug/12	3	3	3	3	3
17Aug/00	m	m	m	m	m
17Aug/12	2	1	3	3	3
18Aug/00	3	3	3	3	1
26Aug/12	m	m	m	m	m
27Aug/00	3	3	3	1	3
27Aug/12	3	3	3	3	3
06Sep/00	m	m	m	m	m
06Sep/12	2	2	3	3	3
07Sep/00	2	2	3	3	3
15Sep/12	m	m	m	m	m
16Sep/00	2	1	3	3	3
16Sep/12	3	3	3	3	3
26Sep/00	m	m	m	m	m
26Sep/12	3	3	3	3	3
27Sep/00	3	3	3	3	3
05Oct/12	m	m	m	m	m
06Oct/00	3	3	3	3	3
06Oct/12	1	3	1	1	1

TABLE F2: Continued.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
16Oct/00	m	m	m	m	m
16Oct/12	1	1	1	3	1
17Oct/00	3	3	3	3	3
25Oct/12	m	m	m	m	m
26Oct/00	3	3	3	3	3
26Oct/12	3	3	3	3	3
05Nov/00	m	m	m	m	m
05Nov/12	3	3	3	3	3
06Nov/00	3	3	3	3	3
14Nov/12	m	m	m	m	m
15Nov/00	1	3	3	3	3
15Nov/12	1	1	1	3	1
25Nov/00	m	m	m	m	m
25Nov/12	3	1	3	3	3
26Nov/00	1	1	1	1	1
04Dec/12	m	m	m	m	m
05Dec/00	1	3	3	1	1
05Dec/12	1	1	1	3	1
15Dec/00	m	m	m	m	m
15Dec/12	1	1	1	1	1
16Dec/00	3	3	3	3	3
24Dec/12	m	m	m	m	m
25Dec/00	1	1	1	3	3
25Dec/12	1	1	1	3	1

TABLE F3: Verification Category Results for North Platte, Nebraska. Labels as in Table F1.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
10Jan/00	m	m	m	m	m
10Jan/12	1	3	3	3	1
11Jan/00	3	3	3	3	3
19Jan/12	m	m	m	m	m
20Jan/00	3	3	1	1	3
20Jan/12	1	1	3	1	1
30Jan/00	m	m	m	m	m
30Jan/12	3	3	1	1	1
31Jan/00	1	1	1	1	1
08Feb/12	m	m	m	m	m
09Feb/00	3	3	3	3	3
09Feb/12	1	1	3	3	1
19Feb/00	m	m	m	m	m
19Feb/12	1	3	3	3	1
20Feb/00	3	3	3	3	3
28Feb/12	m	m	m	m	m
29Feb/00	3	3	3	3	3
29Feb/12	1	1	1	1	1
10Mar/00	m	m	m	m	m
10Mar/12	1	1	1	3	1
11Mar/00	m	m	m	m	m
19Mar/12	m	m	m	m	m
20Mar/00	1	3	3	3	3
20Mar/12	1	1	1	3	1
30Mar/00	m	m	m	m	m
30Mar/12	1	3	3	3	3
31Mar/00	3	1	3	1	1
08Apr/12	m	m	m	m	m
09Apr/00	3	3	3	1	3
09Apr/12	1	1	1	1	3
19Apr/00	m	m	m	m	m
19Apr/12	3	3	3	1	3
20Apr/00	3	3	3	3	3
28Apr/12	m	m	m	m	m
29Apr/00	3	3	3	3	1
29Apr/12	1	3	1	3	1
09May/00	m	m	m	m	m
09May/12	3	3	1	1	1
10May/00	1	1	1	3	3
18May/12	m	m	m	m	m
19May/00	3	3	3	3	3
19May/12	1	1	1	3	1

TABLE F3: Continued.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
29May/00	m	m	m	m	m
29May/12	1	1	1	1	1
30May/00	3	1	1	3	1
07Jun/12	m	m	m	m	m
08Jun/00	1	1	1	3	3
08Jun/12	1	1	1	1	1
18Jun/00	m	m	m	m	m
18Jun/12	1	3	1	3	1
19Jun/00	3	3	3	3	3
27Jun/12	m	m	m	m	m
28Jun/00	3	3	3	3	3
28Jun/12	1	3	1	1	3
08Jul/00	m	m	m	m	m
08Jul/12	m	m	m	m	m
09Jul/00	m	m	m	m	m
17Jul/12	m	m	m	m	m
18Jul/00	3	3	3	3	3
18Jul/12	3	3	3	3	3
28Jul/00	m	m	m	m	m
28Jul/12	m	m	m	m	m
29Jul/00	m	m	m	m	m
06Aug/12	m	m	m	m	m
07Aug/00	3	3	3	3	3
07Aug/12	3	3	3	3	1
17Aug/00	m	m	m	m	m
17Aug/12	3	3	3	3	3
18Aug/00	3	3	3	3	3
26Aug/12	m	m	m	m	m
27Aug/00	3	3	3	3	3
27Aug/12	3	3	3	3	1
06Sep/00	m	m	m	m	m
06Sep/12	1	1	1	3	3
07Sep/00	3	3	3	3	3
15Sep/12	m	m	m	m	m
16Sep/00	3	1	3	3	3
16Sep/12	3	3	3	1	3
26Sep/00	m	m	m	m	m
26Sep/12	3	3	3	3	3
27Sep/00	2	2	3	3	3
05Oct/12	m	m	m	m	m
06Oct/00	3	3	3	3	3
06Oct/12	3	3	3	3	3

TABLE F3: Continued.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
16Oct/00	m	m	m	m	m
16Oct/12	1	1	1	1	1
17Oct/00	1	3	3	1	3
25Oct/12	m	m	m	m	m
26Oct/00	3	3	3	3	3
26Oct/12	3	3	3	3	3
05Nov/00	m	m	m	m	m
05Nov/12	1	1	1	1	1
06Nov/00	3	1	3	3	3
14Nov/12	m	m	m	m	m
15Nov/00	3	3	3	3	3
15Nov/12	3	3	3	3	3
25Nov/00	m	m	m	m	m
25Nov/12	1	1	1	1	1
26Nov/00	1	1	1	3	3
04Dec/12	m	m	m	m	m
05Dec/00	3	3	3	3	3
05Dec/12	1	1	1	3	1
15Dec/00	m	m	m	m	m
15Dec/12	3	3	3	3	3
16Dec/00	3	3	3	1	3
24Dec/12	m	m	m	m	m
25Dec/00	3	3	3	4	3
25Dec/12	1	1	1	1	1

TABLE F4: Verification Category Results for Vandenburg AFB, California. Labels as in Table F1.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
10Jan/00	1	1	1	3	m
10Jan/12	m	m	m	m	m
11Jan/00	3	3	1	3	1
19Jan/12	m	m	m	m	m
20Jan/00	3	3	3	3	3
20Jan/12	m	m	m	m	m
30Jan/00	m	m	m	m	m
30Jan/12	m	m	m	m	m
31Jan/00	3	3	3	3	3
08Feb/12	m	m	m	m	m
09Feb/00	1	3	3	1	3
09Feb/12	3	3	3	1	3
19Feb/00	m	m	m	m	m
19Feb/12	m	m	m	m	m
20Feb/00	3	3	3	3	3
28Feb/12	m	m	m	m	m
29Feb/00	2	3	3	3	3
29Feb/12	m	m	m	m	m
10Mar/00	m	m	m	m	m
10Mar/12	m	m	m	m	m
11Mar/00	3	3	3	3	3
19Mar/12	m	m	m	m	m
20Mar/00	3	3	3	1	3
20Mar/12	m	m	m	m	m
30Mar/00	m	m	m	m	m
30Mar/12	m	m	m	m	m
31Mar/00	3	3	3	3	3
08Apr/12	m	m	m	m	m
09Apr/00	3	1	3	3	1
09Apr/12	3	3	3	3	3
19Apr/00	m	m	m	m	m
19Apr/12	m	m	m	m	m
20Apr/00	1	3	3	1	3
28Apr/12	m	m	m	m	m
29Apr/00	1	3	3	1	3
29Apr/12	m	m	m	m	m
09May/00	m	m	m	m	m
09May/12	m	m	m	m	m
10May/00	1	3	1	3	3
18May/12	m	m	m	m	m
19May/00	3	3	3	3	3
19May/12	m	m	m	m	m

TABLE F4: Continued.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
29May/00	m	m	m	m	m
29May/12	1	3	3	3	3
30May/00	3	3	3	3	3
07Jun/12	m	m	m	m	m
08Jun/00	1	1	1	3	3
08Jun/12	m	m	m	m	m
18Jun/00	m	m	m	m	m
18Jun/12	m	m	m	m	m
19Jun/00	1	1	1	1	3
27Jun/12	m	m	m	m	m
28Jun/00	3	3	3	1	3
28Jun/12	m	m	m	m	m
08Jul/00	m	m	m	m	m
08Jul/12	m	m	m	m	m
09Jul/00	m	m	m	m	m
17Jul/12	m	m	m	m	m
18Jul/00	1	3	1	3	3
18Jul/12	m	m	m	m	m
28Jul/00	m	m	m	m	m
28Jul/12	m	m	m	m	m
29Jul/00	m	m	m	m	m
06Aug/12	m	m	m	m	m
07Aug/00	1	1	1	3	3
07Aug/12	m	m	m	m	m
17Aug/00	m	m	m	m	m
17Aug/12	m	m	m	m	m
18Aug/00	1	1	1	1	3
26Aug/12	m	m	m	m	m
27Aug/00	3	3	3	3	3
27Aug/12	m	m	m	m	m
06Sep/00	m	m	m	m	m
06Sep/12	m	m	m	m	m
07Sep/00	3	3	3	3	3
15Sep/12	m	m	m	m	m
16Sep/00	3	3	3	3	3
16Sep/12	m	m	m	m	m
26Sep/00	m	m	m	m	m
26Sep/12	3	3	3	3	3
27Sep/00	1	1	1	1	3
05Oct/12	m	m	m	m	m
06Oct/00	3	3	3	1	3
06Oct/12	m	m	m	m	m

TABLE F4: Continued.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
16Oct/00	m	m	m	m	m
16Oct/12	m	m	m	m	m
17Oct/00	3	3	3	3	3
25Oct/12	m	m	m	m	m
26Oct/00	1	3	3	3	3
26Oct/12	m	m	m	m	m
05Nov/00	m	m	m	m	m
05Nov/12	3	3	3	3	3
06Nov/00	3	3	3	1	3
14Nov/12	m	m	m	m	m
15Nov/00	1	3	3	1	1
15Nov/12	m	m	m	m	m
25Nov/00	m	m	m	m	m
25Nov/12	m	m	m	m	m
26Nov/00	1	3	1	1	1
04Dec/12	m	m	m	m	m
05Dec/00	3	3	3	3	3
05Dec/12	m	m	m	m	m
15Dec/00	m	m	m	m	m
15Dec/12	1	1	3	3	1
16Dec/00	3	3	3	1	3
24Dec/12	m	m	m	m	m
25Dec/00	3	3	3	3	1
25Dec/12	m	m	m	m	m

TABLE F5: Verification Category Results for Grand Junction, Colorado. Labels as in Table F1.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
10Jan/00	m	m	m	m	m
10Jan/12	1	1	3	1	1
11Jan/00	3	3	3	3	3
19Jan/12	m	m	m	m	m
20Jan/00	3	3	3	3	3
20Jan/12	3	1	3	3	1
30Jan/00	m	m	m	m	m
30Jan/12	3	3	3	1	1
31Jan/00	3	3	3	1	1
08Feb/12	m	m	m	m	m
09Feb/00	3	1	1	3	3
09Feb/12	1	1	1	1	1
19Feb/00	m	m	m	m	m
19Feb/12	1	1	1	1	1
20Feb/00	3	3	3	3	3
28Feb/12	m	m	m	m	m
29Feb/00	3	3	3	3	3
29Feb/12	3	3	3	3	3
10Mar/00	m	m	m	m	m
10Mar/12	1	1	1	1	1
11Mar/00	3	3	3	3	3
19Mar/12	m	m	m	m	m
20Mar/00	3	3	3	3	3
20Mar/12	1	1	1	1	1
30Mar/00	m	m	m	m	m
30Mar/12	3	3	3	3	3
31Mar/00	3	3	3	3	3
08Apr/12	m	m	m	m	m
09Apr/00	3	2	2	3	3
09Apr/12	1	3	1	1	1
19Apr/00	m	m	m	m	m
19Apr/12	3	3	3	3	3
20Apr/00	3	2	3	3	3
28Apr/12	m	m	m	m	m
29Apr/00	3	1	2	4	2
29Apr/12	1	1	3	3	1
09May/00	m	m	m	m	m
09May/12	1	3	3	1	1
10May/00	2	2	2	3	2
18May/12	m	m	m	m	m
19May/00	3	2	3	4	2
19May/12	1	3	3	4	1

TABLE F5: Continued.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
29May/00	m	m	m	m	m
29May/12	3	3	3	1	1
30May/00	3	2	2	3	2
07Jun/12	m	m	m	m	m
08Jun/00	3	3	3	3	3
08Jun/12	1	3	1	1	1
18Jun/00	m	m	m	m	m
18Jun/12	1	3	3	3	1
19Jun/00	3	2	2	3	3
27Jun/12	m	m	m	m	m
28Jun/00	3	3	3	3	3
28Jun/12	3	3	3	3	1
08Jul/00	m	m	m	m	m
08Jul/12	m	m	m	m	m
09Jul/00	m	m	m	m	m
17Jul/12	m	m	m	m	m
18Jul/00	3	3	3	3	3
18Jul/12	3	3	3	3	1
28Jul/00	m	m	m	m	m
28Jul/12	m	m	m	m	m
29Jul/00	3	3	3	3	3
06Aug/12	m	m	m	m	m
07Aug/00	3	2	2	3	3
07Aug/12	1	3	3	1	1
17Aug/00	m	m	m	m	m
17Aug/12	3	3	3	3	3
18Aug/00	2	2	2	3	3
26Aug/12	m	m	m	m	m
27Aug/00	3	3	3	3	3
27Aug/12	3	3	3	3	1
06Sep/00	m	m	m	m	m
06Sep/12	1	3	3	1	1
07Sep/00	1	3	3	1	3
15Sep/12	m	m	m	m	m
16Sep/00	3	3	3	3	3
16Sep/12	1	1	1	3	1
26Sep/00	m	m	m	m	m
26Sep/12	3	3	3	1	1
27Sep/00	3	2	2	3	3
05Oct/12	m	m	m	m	m
06Oct/00	3	3	1	3	3
06Oct/12	1	1	1	1	1

TABLE F5: Continued.

Date/Time	Anal	PIMIX	POTEMP	RICH	TKE
16Oct/00	m	m	m	m	m
16Oct/12	1	3	3	1	1
17Oct/00	3	3	3	3	3
25Oct/12	m	m	m	m	m
26Oct/00	3	2	3	3	3
26Oct/12	3	3	3	3	3
05Nov/00	m	m	m	m	m
05Nov/12	1	1	3	3	1
06Nov/00	2	2	3	3	3
14Nov/12	m	m	m	m	m
15Nov/00	3	3	3	3	3
15Nov/12	3	3	3	3	3
25Nov/00	m	m	m	m	m
25Nov/12	1	1	3	1	1
26Nov/00	3	3	3	3	3
04Dec/12	m	m	m	m	m
05Dec/00	3	3	3	3	3
05Dec/12	1	1	1	3	1
15Dec/00	m	m	m	m	m
15Dec/12	3	3	3	3	3
16Dec/00	3	3	1	3	3
24Dec/12	m	m	m	m	m
25Dec/00	3	3	3	1	3
25Dec/12	1	1	1	1	1

Glossary of Terms

4DDA: Four Dimensional Data Assimilation

AFTAC: The Air Force Technical Applications Center

EYW: Station identifier for Key West, Florida

GJT: Station identifier for Grand Junction, Colorado

ISAN: RAMS Isentropic Analysis Package

LBF: Station identifier for North Platte, Nebraska

LCH: Station identifier for Lake Charles, Louisiana

MSLP: Mean Sea Level Pressure

NCAR: National Center for Atmospheric Research

NCEP: National Center for Environmental Prediction

PBL: Planetary Boundary Layer

PIMIX: Potential Instability Mixing Depth Routine

POTEMP: Potential Temperature Algorithm

RAMS: Regional Atmospheric Modeling System

RH: Relative Humidity

RICH: The Gradient Richardson Method

RMS: Root Mean Square

SLAM: Short-Ranged Layered Atmospheric Model

TKE: Turbulent Kinetic Energy

UTC: Universal Coordinated Time

VBG: Station identifier for Vandenburg AFB, California

WMO: World Meteorological Organization

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13. ABSTRACT *(Maximum 200 words)*
Diffusion-Transport (D-T) modeling is a branch of numerical weather prediction concerned with eddy diffusion of particulate pollutant plumes and their transport by the wind. When conducting D-T modeling, establishing the height of the planetary boundary layer (PBL) is crucial to defining the vertical bounds within which a plume can become thoroughly mixed. The PBL can be deduced from observations or model simulation.

Three sounding analysis PBL algorithms were considered-the Potential Instability Mixing Depth (PIMIX), Potential Temperature (POTEMP), and Gradient Richardson Number (RICH) algorithms. A turbulent kinetic energy (TKE) based PBL algorithm was also evaluated. The purpose of this research was threefold. First, observed atmospheric soundings were input, and algorithm output was compared to human analyses of the observed soundings (Analysis). Second, Regional Atmospheric Modeling System (RAMS) generated forecast soundings were input, and algorithm output was compared to human analyses of the forecast soundings (Simulation). Finally, algorithm output from simulation was compared with the human analyses from analysis (Verification). These PBL comparisons were put into one of four categories: (1) hit, (2) indication of deep convection, (3) miss, or (4) algorithm failure. Algorithm performance was ranked based on the number of hits, then on indications of deep convection.

PIMIX was the best analysis tool, while both POTEMP and TKE were the best simulation methods. All algorithms had a similar number of hits for verification, but PIMIX had more estimates indicative of deep convection, so was ranked best.

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