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METHODOLOGY INVESTIGATION

FINAL REPORT

ATMOSPHERIC TRANSPORT AND DISPERSION MODEL HIERARCHY, PART II

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DUGWAY, UTAH 84022-5000

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2 MAR 1990

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SUBJECT: Final Report: Atmospheric Transport and Dispersion Model Hierarchy, Part II, TECOM Project No. 7-CO-R89-DPO-013

1. Subject report is approved.

2. Point of contact at this headquarters is Mr. James Piro, AMSTE-TC-M, amstetcm@apg-emh4.apg.army.mil, AUTOVON 298-2170.

FOR THE COMMANDER:

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U.S. Army Dugway Proving Ground (DPG) conducted a methodology investigation to identify the numerical mesoscale modeling approach best suited for operational use in predicting DPG test grid winds up to 24 hours in advance. The selection criteria for the models were that they be: (1) existing models that have been successfully applied to mesoscale flows in complex terrain, (2) nonproprietary, and (3) available. The three models acquired during the study that satisfied these criteria were the U.S. Army Atmospheric Sciences Laboratory (ASL) model hierarchy, the Los Alamos National Laboratory (LANL) HOTMAC model, and Jan Paegle's BLAYER model. Initial work with the SIGMET model, the prognostic component of the ASL model hierarchy, identified a number of problems when the model was applied to DPG terrain with a grid resolution of 5 km. After DPG attempted to correct many of these problems, the revised SIGMET model showed promise in its ability
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to predict DPG wind fields, but the computer execution time was prohibitive. LANL, which is currently updating the SIGMET model under contract to ASL, has identified problems similar to those found by DPG. Also, LANL is changing the model's code to reduce computation time. To avoid a duplication of effort, no further work was done with the ASL model hierarchy. Five historical cases were used to evaluate the performance of the BLAYER and HOTMAC models at DPG. These cases included days with diurnal wind regimes and days when DPG winds are believed to have been determined by the interaction of synoptic and mesoscale influences. The models were used to forecast wind fields for 24-hr periods beginning at midnight on each historical case. The model's predictions were compared with the winds measured by DPG's Mesonet system of remote weather stations. The two models demonstrated different strengths and weaknesses in predicting DPG wind fields. In general, the BLAYER model's predictions best agreed with the measurements at night when there were drainage winds, while the HOTMAC model's predictions best agreed with the measurements during the day when there were upslope winds. Because no single model demonstrated a clear superiority in predicting DPG winds under all meteorological conditions or at all times of the day, it is recommended that DPG adapt both the BLAYER and HOTMAC models for operational use.

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FOREWORD

This project was partially supported by FY89 Research, Development, Test, and Evaluation (RDTE) methodology funds. Dr. Gregory Dodd's participation in this study was provided by the H. E. Cramer Company, Inc. under Work Assignment M-8 of Contract No. DAAD09-87-D-0038. The authors also acknowledge the contributions of the following H. E. Cramer Company employees and consultants: Mr. Harry Geary, Mr. Jay Bjorklund, Dr. Jan Paegle, and Mr. William Ohmstede. Mr. Ronald Cionco of U.S. Army Atmospheric Sciences Laboratory (ASL) made the ASL model hierarchy available for use in this study, and Dr. Michael D. Williams of Los Alamos National Laboratory (LANL) provided helpful suggestions on the use of both the ASL model hierarchy and the LANL HOTMAC model. This report was typed by Mrs. Susan Gross, Meteorology Division, U.S. Army Dugway Proving Ground.

SECTION 1. SUMMARY

1.1 BACKGROUND

The mission of U.S. Army Dugway Proving Ground (DPG) includes the conduct of chemical simulant and smoke/obscurant field tests. Because the results of these tests are highly dependent on meteorological conditions, most are intended to be conducted within specified meteorological constraints (wind speed, temperature, stability, etc.). Also, safety and environmental considerations can impose additional meteorological limitations on test conduct (wind direction, stability, etc.). Because DPG test schedules on a given day are normally finalized on the afternoon of the preceding day, forecasts of test grid meteorological conditions are used to assist in making go/no-go test decisions for the following day. The accuracy of synoptic-scale weather forecasts for the DPG area is limited by factors, such as the complexity of the terrain and the variability of surface thermodynamic characteristics, that can significantly affect local circulations. As an example, surface wind directions that differ by 180 degrees from synoptic-scale wind directions are common at DPG.

DPG forecasters currently rely primarily on professional judgment to modify synoptic-scale weather forecasts to account for local (mesoscale) influences. A potential alternative to subjective modifications of synoptic-scale forecasts is provided by numerical mesoscale models. These models use numerical techniques to predict future conditions by solving the equations of motion and the conservation equations for mass and energy. As might be expected, these models are very computer intensive. Until recently, the typical numerical mesoscale model has required about 1 minute of execution time on a large main-frame computer to predict the evolution of meteorological conditions over a 1-minute period. Consequently, numerical mesoscale models have been limited to research rather than operational applications. However, recent advances in computer technology in combination with advances in numerical mesoscale models have brought these models to the brink of operational practicality. If a numerical mesoscale model can be adapted for routine operational use at DPG, it can then be coupled with a dispersion model to provide forecasts of the results of dissemination tests up 24 hours in advance.

1.2 PROBLEM

During Part I of this study (Bowers and Astling, 1988), DPG attempted to acquire and evaluate three numerical mesoscale models with the potential for predicting DPG test grid winds 24 to 36 hours in advance. Based on the current literature and papers presented at recent scientific conferences, the three models appeared to satisfy the criteria that they be: (1) existing models that have been successfully applied to mesoscale flows in similar settings, (2) nonproprietary, and (3) available. DPG was successful in its attempts to acquire two of the three models, the U.S. Army Atmospheric Sciences Laboratory (ASL) model hierarchy (Cionco, 1986) and the BLAYER model (Paegle and McLawhorn, 1983). The developer of the third model, the Los Alamos National Laboratory (LANL) HOTMAC model (Yamada and Bunker, 1988), declined to make the model available until he completed a simplified version for operational use at U.S. Army chemical storage depots. DPG found the ASL model hierarchy and the BLAYER model to be undocumented and very complex. Although DPG was eventually able to implement both models on a DPG computer system, it was necessary to devote the entire Phase I effort to learning how to run the models because of their complexity and the lack of any documentation.

1.3 OBJECTIVE

Identify the mesoscale modeling approach best suited for predicting DPG wind fields.

1.4 PROCEDURES

The study was divided into two major phases. In the first phase, the SIGMET model of the ASL model hierarchy and the BLAYER model were qualitatively evaluated to identify any model problems specific to DPG applications. The HOTMAC model was not considered in this phase because it was not received by DPG until the last month of the study. The second phase of the study consisted of comparisons of model predictions for historical cases with observed DPG wind fields.

1.5 RESULTS AND ANALYSIS

Qualitative tests of the SIGMET model, the predictive component of the ASL model hierarchy, revealed several problems when the model was applied to DPG terrain with a grid resolution of 5 kilometers. These problems, most of which were related to the surface energy budget and the lateral boundary conditions, likely do not occur with less complex terrain and a larger separation of grid points. Although DPG attempted to correct these problems, the validity of these changes cannot be determined without a much more detailed knowledge of the model. The revised version of the SIGMET model showed promise in its ability to predict DPG wind fields, but the computer execution time was prohibitive. LANL is currently updating the SIGMET model under contract to ASL. This work appears to have identified some of the same problems as found in this study. Also, the model's equations are being rewritten in a form that significantly reduces computation time. To avoid an unnecessary duplication of effort, no further work was done with the ASL model hierarchy in this study. If funds permit, work with the SIGMET model will be resumed after the updated version of the model is received from ASL.

Work during the Part I study demonstrated that the BLAYER model is capable of reproducing the major features of the diurnal wind regime (nighttime drainage winds and daytime upslope winds) that is observed at DPG in the absence of strong synoptic-scale pressure gradients. The Phase I work also suggested that the model requires a dense grid resolution to account for local topographic and thermodynamic influences on DPG winds. One way to achieve a dense grid resolution without increasing computation time to a prohibitive extent is to nest a dense inner grid within a large-scale grid with a much coarser grid resolution. As part of this study, DPG developed a nested grid version of the BLAYER model. However, this nested grid version did not perform better than the single grid (original) version with only the small, inner grid. Possible explanations for the poor performance of the nested grid version include: (1) the large-scale solution is very sensitive to the horizontal resolution, (2) the boundary values for the inner grid are not adequately described by interpolation of the large-scale results, and (3) small-scale motions in the inner grid may have a significant impact on the large-scale flow surrounding the inner domain. If the first explanation is correct, a nested grid version of the model is not feasible at DPG because of the complexity of the terrain. If the second and third explanations are correct, the problems might be solved by employing a two-way interactive nested grid model. Because the development of a two-way interactive model is much more difficult than the development of a one-way interactive model, no further attempts were made to develop a nested grid version of the BLAYER model.

Five historical cases were selected for the quantitative evaluation of the BLAYER and HOTMAC models. These cases included days with diurnal wind regimes and days when DPG winds are believed to have been determined by the interaction of synoptic and mesoscale influences. The models were used to forecast wind fields for 24-hour periods beginning at midnight on each historical case. Upper-air soundings routinely made each afternoon at the Salt Lake City International Airport were used to develop the model meteorological inputs that define the initial synoptic-scale conditions for the historical cases. The predicted wind fields at 10 meters above the surface were compared with the winds measured by DPG's Mesonet system of remote weather stations. The calculated wind fields were depicted as wind vector plots for qualitative comparisons with the Mesonet winds and were interpolated to the locations of the Mesonet stations for quantitative comparisons. The root-mean-square (RMS) difference between predictions and measurements was used as the quantitative measure of model performance.

The BLAYER and HOTMAC models demonstrated different relative strengths and weaknesses in predicting DPG wind fields. The wind fields predicted by the HOTMAC model were consistently lighter and more smoothed than those predicted by the BLAYER model. Not only were winds predicted by the BLAYER model more sensitive to local influences than those predicted by the HOTMAC model, they were also more sensitive to the initial synoptic-scale conditions. In general, the BLAYER model's predictions best agreed with the measurements at night when there were drainage winds, while the HOTMAC model's predictions best agreed with the measurements during the day when there were upslope winds. The HOTMAC model's RMS differences between predictions and measurements were smaller than the BLAYER model's RMS differences except during periods with well defined drainage winds. These quantitative results can be misleading, however. For example, small RMS values sometimes reflected the low magnitudes of the predicted and measured winds rather than a high degree of forecast skill. Also, large RMS values sometimes occurred when a model described the orientation of the flow with accuracy, but over- or underestimated its magnitude.

1.6 CONCLUSIONS

No single numerical mesoscale model demonstrated a clear superiority in predicting DPG test grid winds under all meteorological conditions or at all times of the day. In general, the BLAYER model performed best at night with drainage winds and the HOTMAC model performed best during the day with upslope flows. The BLAYER model's performance during the day was often poor because of the model's tendency to overemphasize the effects of local topographic influences. This sensitivity to local influences is actually encouraging because it suggests that an improved grid resolution might significantly improve the BLAYER model's performance. Also, work by Astling (1989) in a related study has shown that the BLAYER model's predictions are very sensitive to horizontal variations in surface thermodynamic characteristics, which were assumed to be horizontally uniform in this study. Thus, an improved representation of surface characteristics might contribute to a significant improvement in the BLAYER model's performance at DPG. The HOTMAC model probably did not receive a fair test in this investigation because the model was received too late in the study for DPG to gain any experience with it before performing the historical calculations. The HOTMAC model also has features such as its unique "nudging" term in the equations of motion that were not used in this study because of the lack of technical guidance in the model's documentation. These features need to be investigated to determine if they can improve the model's performance at DPG.

There is a precedent in synoptic-scale meteorology for the use of more than one numerical model to assist in weather forecasts. As in the case of the numerical mesoscale models evaluated in this study, different numerical synoptic-scale models have different strengths and weaknesses. Typically, these models must be routinely used for a year or more before forecasters can judge when the model's predictions can be used with and without adjustment and when they are totally unreliable. The synoptic-scale precedent suggests that DPG should continue work with both the BLAYER and HOTMAC models. This conclusion is reinforced by the fact there are many areas for possible improvement in the performance of both models.

1.7 RECOMMENDATIONS

DPG should continue efforts to adapt the BLAYER and HOTMAC models for operational use in predicting test grid winds. These efforts should consist of additional evaluations of how model performance can be improved by means such as improved grid resolutions and more accurate representations of surface thermodynamic characteristics. With each model, the feasibility of a nested grid version or of coupling the model to a higher resolution diagnostic model (for example, the ASL model hierarchy's VARYME model) should be investigated as a way to incorporate the smaller scale influences on DPG test grid winds. Attempts should also be made to reduce the BLAYER and HOTMAC models' computer execution times to the extent that they become practical for routine use. These reductions probably can be achieved through a combination of planned improvements in DPG computer resources, simplifications in some model algorithms, and optimization of computational grids and time steps. The two models should then be routinely executed on normal work days to gain the experience necessary before one or both of the models can be used operationally as a forecast aid.

SECTION 2. DETAILS OF THE INVESTIGATION

2.1 DESCRIPTION OF MESOSCALE MODELS

2.1.1. The ASL Model Hierarchy. The ASL model hierarchy (Cionco, 1986) is a nested set of prognostic (predictive) and diagnostic (descriptive) models that is designed to integrate synoptic-scale, mesoscale, and microscale influences on wind and temperature fields. The three major components of the hierarchy are the SIGMET model (Patniak and Freeman, 1983), the VARYME model (Ohmstede, 1979), and the HRW model (Ohmstede, 1984). Synoptic scale meteorological data are used as input to the prognostic SIGMET model, which typically is applied to a computational domain on the order of 200 kilometers on a side with a horizontal grid resolution of 10 kilometers. The SIGMET model's output serves as input to the finer resolution VARYME model, which is usually applied to a computational domain on the order of 80 kilometers on a side with a horizontal resolution of 1 kilometer. The output from the diagnostic VARYME model in turn serves as input to the high resolution HRW model, a diagnostic model which computes the surface layer wind and temperature fields with a typical horizontal resolution of 100 meters. Because the HRW model was not used in this study, it is not further described in this report.

The SIGMET model is a three-dimensional, multilevel model that numerically solves the equations of motion (Navier-Stokes equations) and the conservation equations for mass and energy. These "primitive equations" are written in an Eulerian (fixed) coordinate system. The model uses the hydrostatic approximation (buoyancy forces are exactly balanced by gravity) and an essentially terrain-following coordinate system formulated in terms of pressure rather than height.

The VARYME model is a three-dimensional, single-layer model. The lower layer boundary is defined by the terrain and the upper boundary is defined by the top of the planetary boundary layer. This hydrostatic model also uses a terrain following coordinate system in which the vertical coordinate is the variable thickness of the layer. The model, which applies a layer integral operator to the primitive equations, considers turbulence and the fluxes of heat and moisture, but not viscous effects. The VARYME model uses an objective variational analysis technique to adjust the SIGMET model's relatively coarse predicted wind and temperature fields until mass- and energy-consistent wind and temperature fields are obtained. These adjusted wind and temperature fields reflect the finer resolution of the terrain used in the VARYME model calculations.

2.1.2 The BLAYER Model. The BLAYER model is an updated version of the model described by Paegle and McLawhorn (1983). This hydrostatic model uses the primitive equations in an Eulerian coordinate system, with the model's terrain-following vertical coordinate extending 2 kilometers above the terrain in the model version used during the Part I study. The BLAYER model calculates the surface energy budget, including the sensible heat fluxes to the atmosphere and soil, solar radiation, and terrestrial radiation. A subsurface soil layer is explicitly included in these calculations. The only gas considered in the radiative transfer calculations is water vapor. A steady external forcing is imposed at the top of the computational domain by specifying the pressure field, geostrophic wind, and temperature.

During the Part I study, Paegle made three modifications in the BLAYER model for application to DPG. First, the mixing length parameterization of vertical turbulent mixing was replaced by a Richardson number parameterization. Second, the vertically stretched coordinate transformation was replaced by an exponential vertical grid spacing. Third, the soil hydrology model was highly simplified. The modified BLAYER model ran in about 75 percent of the previously required execution time. Also, it appeared to be much less sensitive to non-linear computational instabilities that sometimes adversely affect the model solutions after about 12 hours of prediction time.

Paegle made two additional changes in the BLAYER model as part of this study. First, the radiation code was changed so that the computational levels can be arbitrarily specified and the radiative flux calculations are made through a column 12 kilometers deep rather than through just the surface boundary layer. These changes allow the vertical placement of grid points to be independent of the radiation code. Paegle's tests of the revised model indicate that the deeper layer provides more realistic radiative flux estimates than the previous version of the model. At the same time, it appears that the revised model can resolve boundary layer flows and turbulence with far fewer vertical levels than the previous version, resulting in reduced computer memory and execution time requirements. The original version of the BLAYER model allowed the synoptic scale wind at the top of the boundary layer to be entered only as an east-west or north-south component. Paegle also enhanced the model to accept a synoptic scale wind from any direction using the method described by Paegle et al. (1983).

2.1.3 The HOTMAC Model. The Higher Order Turbulence Model for Atmospheric Circulations (HOTMAC) (Yamada and Bunker, 1988) is a three-dimensional, multi-level primitive equation model. The model uses the hydrostatic approximation and a terrain following vertical coordinate system. The HOTMAC model considers "higher order" turbulence effects by using semi-empirical expressions to relate second-moment turbulence parameters such as the vertical momentum flux to calculated lower-order variables. This turbulence parameterization is more advanced than that of most other mesoscale models. The model calculates the surface energy budget, including incident solar and long-wave radiation, outgoing long-wave radiation, sensible heat fluxes to the atmosphere and soil, and sensible heat flux. Near sunrise and sunset when the sun's elevation angle is small, the solar radiation at the surface can be reduced by terrain shadows. The effects of these shadows are explicitly considered by the HOTMAC model. As discussed in Subsection 2.1.1, the ASL model hierarchy nests a diagnostic mesoscale model within a prognostic mesoscale model's computational domain and then nests a second diagnostic model within the first diagnostic model's computational domain. This approach is designed to satisfy the simultaneous requirements for a relatively large computational domain and high resolution wind fields in certain areas. In a similar manner, the original HOTMAC model can be nested within itself to address specific areas in finer detail. However, the nested grid feature was removed from the version provided DPG (Williams et al., 1989) to speed computer execution time.

2.2 MESOSCALE MODEL EVALUATION

2.2.1 Approach. The majority of the tests of numerical mesoscale models described in the scientific literature have consisted of qualitative assessments of their ability to reproduce typical flow regimes and/or intercomparisons of the wind predictions by different models for the same regime. Relatively few model evaluations have been based on comparisons of model wind predictions with wind measurements for historical cases, in part because of the computer resources required to execute the models and in part because of the scarcity of mesoscale data sets with sufficient space and time resolution to define mesoscale circulations. Because DPG's Mesonet network of remote weather stations is capable of defining the important features of mesoscale circulations affecting test grid winds, the model evaluation approach selected for use in this study was to compare model wind predictions with Mesonet wind observations for selected historical cases. Qualitative model evaluations were performed prior to conducting these case studies to identify model problems specific to DPG applications.

The terrain covering a 95-kilometer by 95-kilometer area approximately centered on DPG is shown in Figure 1. Elevations in the figure are in meters above mean sea level (MSL), and the contour interval is 200 meters. Major topographic features in Figure 1 include the Stansbury-Onaqui Mountains (the north-south range at the far right of the figure), the Cedar Mountains (the north-south range at the upper center of the figure), and the Dugway Range-Granite Mountain (the southeast-northwest range and peak at the lower center of the figure). DPG test grids are contained within the southeast-northwest valley bounded by the Cedar Mountains and the Dugway Range-Granite Mountain. Figure 2, a close-up view of the topography of the DPG vicinity, shows the locations of most of DPG's Mesonet remote weather stations. Table 1 identifies these Mesonet stations and gives their elevations. The performance of the numerical mesoscale models was judged in this study by their ability to reproduce the 10-meter winds measured by the Mesonet stations shown in Figure 2.

2.2.2 Qualitative Evaluation

2.2.2.1 The ASL Model Hierarchy

Qualitative tests of the SIGMET model, the prognostic component of the ASL model hierarchy, identified several problems when the model was applied to the terrain shown in Figure 1 with the 5-kilometer grid spacing needed to resolve major topographic features. First, large oscillations occurred in the surface temperature fields. Examination of the code and sensitivity tests indicated that these oscillations were caused by the model's failure to calculate longwave radiative fluxes every time step. The model calculates these fluxes once every 20 time steps and uses extrapolation to obtain fluxes for intermediate time steps. In the DPG simulations, this extrapolation generated sufficient error that there was a significant adjustment in surface temperatures when the fluxes were recomputed at the start of the next 20 time steps. A feedback mechanism caused these adjustments to increase in magnitude as the simulation continued. The problem was solved by changing a parameter so that the flux calculations are made each time step. Another problem was the occurrence of unrealistic surface temperatures during periods of rapid change in solar insolation. This problem was caused by the use of an extrapolated air temperature to calculate the earth's black-body radiation. The problem was solved by changing the model to use the ground temperature in the radiation calculations. After the grid spacing was reduced to 5 kilometers and the depth of the lowest layer was changed from 200 to 5 meters to resolve near surface winds, the time step had to be reduced to about 5 seconds to avoid computational instabilities.

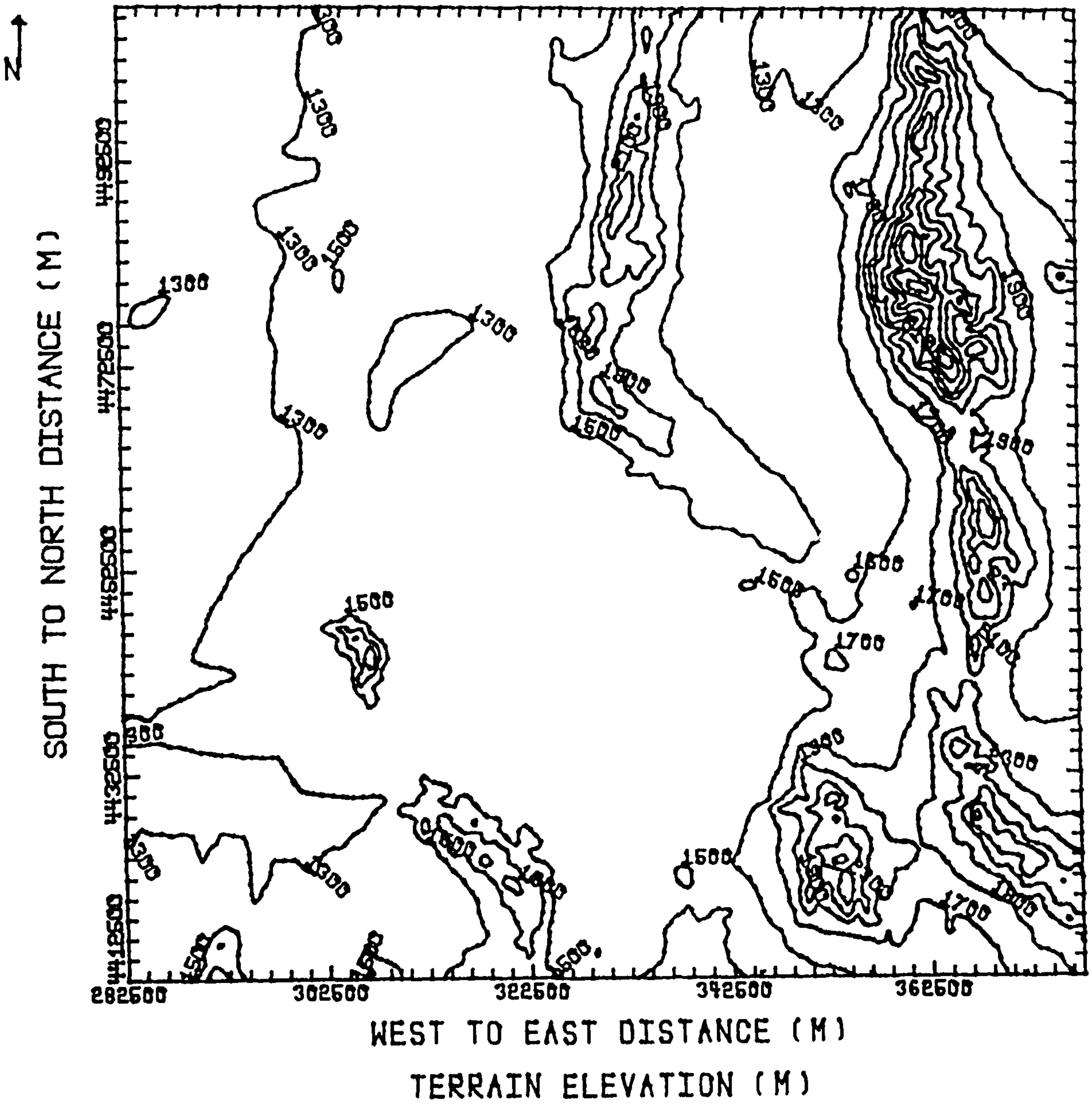


Figure 1. Topographic Map of DPG and the Surrounding Area.

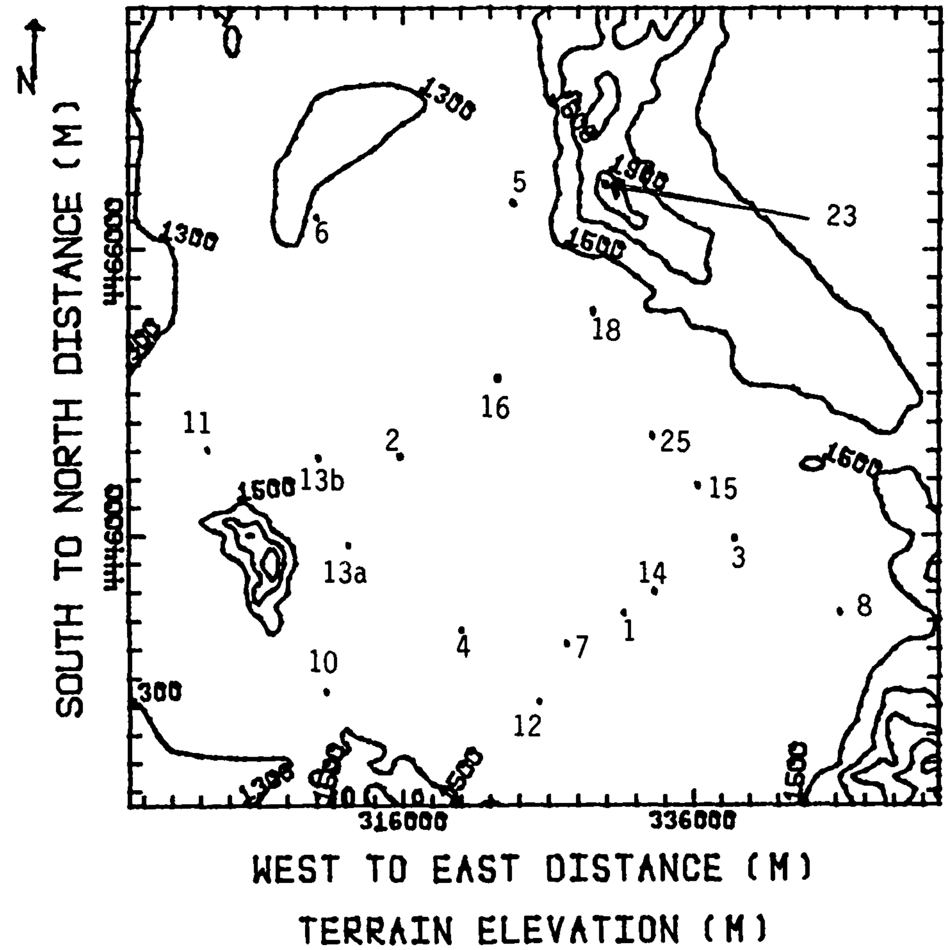


Figure 2. Topographic Map of the DPG Vicinity Showing the Locations of the Mesonet Stations. Stations 13a and 13b are Locations Before and After May 1988, Respectively.

Table 1. Identification of DPG Mesonet Stations.

Station No. in Figure 2	Station Name	Station Elevation (m MSL)
1	Tower Grid	1,330
2	West Vertical Grid	1,311
3	Carr Facility	1,328
4	Delta Road	1,318
5	North Wig	1,331
6	Salt Flats	1,300
7	River Bed	1,331
8	White Sage	1,383
9[a]	Main Gate	1,476
10	Callao Gate	1,327
11	V Grid	1,308
12	Target S Grid	1,333
13	West Stark Road	1,315
14	Camel Back Mountain	1,425
15	Michael Army Airfield (ASL)	1,320
16	Horizontal Grid	1,311
17[a]	NW Salt Flats	1,286
18	Lower Cedar Mountain	1,348
19[a]	Granite Causeway	1,294
20[a]	Clive	1,315
21[a]	Simpson Road	1,390
22[a]	Interstate 80	1,290
23	Upper Cedar Mountain	2,150
24[a]	Fish Springs	1,306
25	NW Decontamination Pad	1,318
26[a]	W Salt Flats	1,292
27[a]	Callao	1,320

[a]Station is outside of area covered by Figure 2.

Even with the changes outlined above, the SIGMET model could not be executed for more than about 2 hours of simulation, apparently because of boundary problems aggravated by DPG's complex terrain. An increase in the eddy viscosity from 200 to 1000 square meters per second and change from Neumann to Dirichlet boundary conditions for the horizontal wind components apparently solved the problem. ("Dirichlet" boundary conditions maintain prescribed parameter values at the lateral boundary, whereas "Neumann" boundary conditions maintain prescribed parameter first derivatives normal to the lateral boundary.) Without the change in lateral boundary conditions, the model predicted unrealistic wind speeds on the order of 30 meters per second within about 1 hour of simulation time. Although the change in boundary conditions resulted in more realistic wind predictions, this change and the other changes may have introduced inconsistencies into the model. A much more intimate knowledge of the model would be required to ensure that these changes are appropriate. An alternative solution to the boundary problem might be to increase the horizontal extent of the computational domain. However, the model already requires 12 hours of computer time to perform a 24-hour simulation for the area shown in Figure 1. Any increase in the horizontal domain would increase the computer time to unreasonable levels.

Meteorological inputs to the SIGMET model consist of the initial profiles of temperature and winds. The modified SIGMET model was used to make a 24-hour DPG wind forecast assuming a mean temperature decrease of 6.5 °C per kilometer over the first 7 kilometers above the surface and winds varying from calm in the planetary boundary layer to westerly at 8 meters per second at 7 kilometers. These inputs are representative of synoptic-scale conditions on 30 August-1 September 1987, the 3-day historical case considered in the Phase I study. The model simulation began at 0000 local (Mountain) standard time (LST) on 31 August 1987.

The SIGMET model predictions of 10-meter winds for 0600, 1200, and 1800 LST on 31 August 1987 and midnight on 1 September 1987 are shown in Figures 3, 4, 5, and 6, respectively. These plots, which show the wind vector calculated at each grid point contained within the area covered by Figure 2, are drawn to the same scale as Figure 2. The orientation of a plotted wind vector shows the predicted direction of the flow and its length is proportional to the predicted wind speed. In each figure, the length of the wind vector with the highest calculated speed is set equal to the horizontal separation between grid points and the lengths of the other wind vectors are scaled accordingly. Thus, the magnitude of the wind speed associated with a wind vector of a specific length varies from figure to figure, depending on the maximum wind speed calculated for the figure. The wind speed that defines this velocity scale is shown at the bottom of each figure. The wind vector plots also show the observed wind vectors by straight lines originating at circles corresponding to the locations of the Mesonet stations. The lengths of these lines define the wind speeds to the same scale as the model predictions, while their orientations show the flow directions. (The flow direction is from rather than towards the circle defining the location of a Mesonet station.) Note that Mesonet Stations 17-27 were not operational at this time.

Inspection of Figures 3 through 6 shows that the SIGMET model's performance is reasonably good for the first 12 hours. As expected, a weakening downslope drainage flow is present at 0600 LST (Figure 3), while an upslope flow has developed at noon (Figure 4). Also, the observed winds in Figures 3 and 4 generally are consistent with the predicted flow fields. However, Figure 5 shows that the model predicts an almost uniform westerly flow at 1800 LST that is in poor agreement with the observations. This wind field does not appear to be significantly affected by local terrain. Although local terrain influences appear to return to the calculated wind field at 0000 LST (Figure 6), the correspondence between predictions and observations remains poor. Lateral boundary problems are the likely cause of the poor model performance beyond 12 hours of simulation.

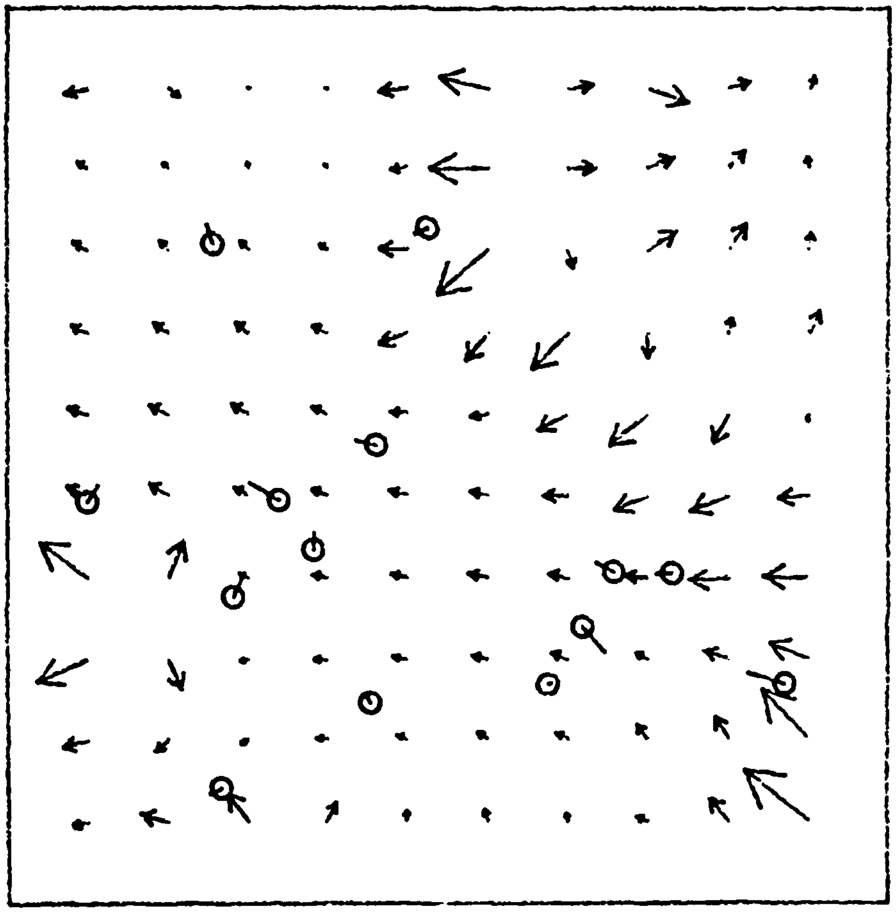
The performance of the SIGMET model for the first 12 hours of the 31 August 1987 test case is encouraging, but the current model's computer execution time requirements are not. Under contract to ASL, LANL substantially reduced these requirements by rewriting the model's equations in "perturbation" form. That is, model parameters are divided into mean and fluctuating (perturbed) components and the model equations are solved for departures from the means. Although the perturbation version of SIGMET has yielded promising results, Cionco of ASL indicated (private communication, 1989) that the new version would not be checked out and available for release to DPG until after the completion date for this study. To avoid an unnecessary duplication of effort, DPG therefore discontinued work with the ASL model hierarchy. If funds permit, this work will be resumed after the perturbation version of the SIGMET model is received from ASL.

2.2.2.2 The BLAYER Model

Work during the Part I study demonstrated that the BLAYER model is capable of reproducing the major features of the diurnal wind regime that is observed at DPG in the absence of strong synoptic-scale pressure gradients. The model's performance was significantly improved when the horizontal domain was increased so that the east-west and north-south grid dimensions were approximately three times larger than those shown in Figure 1. This improvement can be attributed to diminished boundary effects in the interior of the grid and better resolution of the larger scale topographic features. Unfortunately, the increased horizontal domain also significantly increased the computer execution time. Consequently, an attempt was made to develop a nested grid version of the model before beginning the model evaluation. As discussed in Subsection 2.1, this technique can provide both a large computational domain and high resolution wind fields in certain areas.

The nested grid version of the BLAYER model developed as part of this study employs a one-way interaction between the large-scale grid and the embedded inner grid, with the large-scale grid providing time-dependent boundary values of all predicted variables to the inner grid. Because the large scale grid uses a much coarser resolution than the inner grid, it may also use a larger time step and thus further reduce computer execution time. The predictions for the large-scale grid are interpolated: (1) in space to the boundary locations of the inner grid and (2) in time to the shorter time steps of the inner grid. Thus, all predicted variables at the boundaries of the inner grid change with each of the inner grid's time steps. In the current nested version of the BLAYER model, linear interpolation is used over 1-hour intervals because sensitivity tests indicated that the 1-hour time resolution is adequate.

31 aug 1987 0600 lst



vel scale = 8.62 m/s per grid int
06 hour forecast

Figure 3. Wind Vectors Predicted by SIGMET for 0600 LST on 31 August 1987.

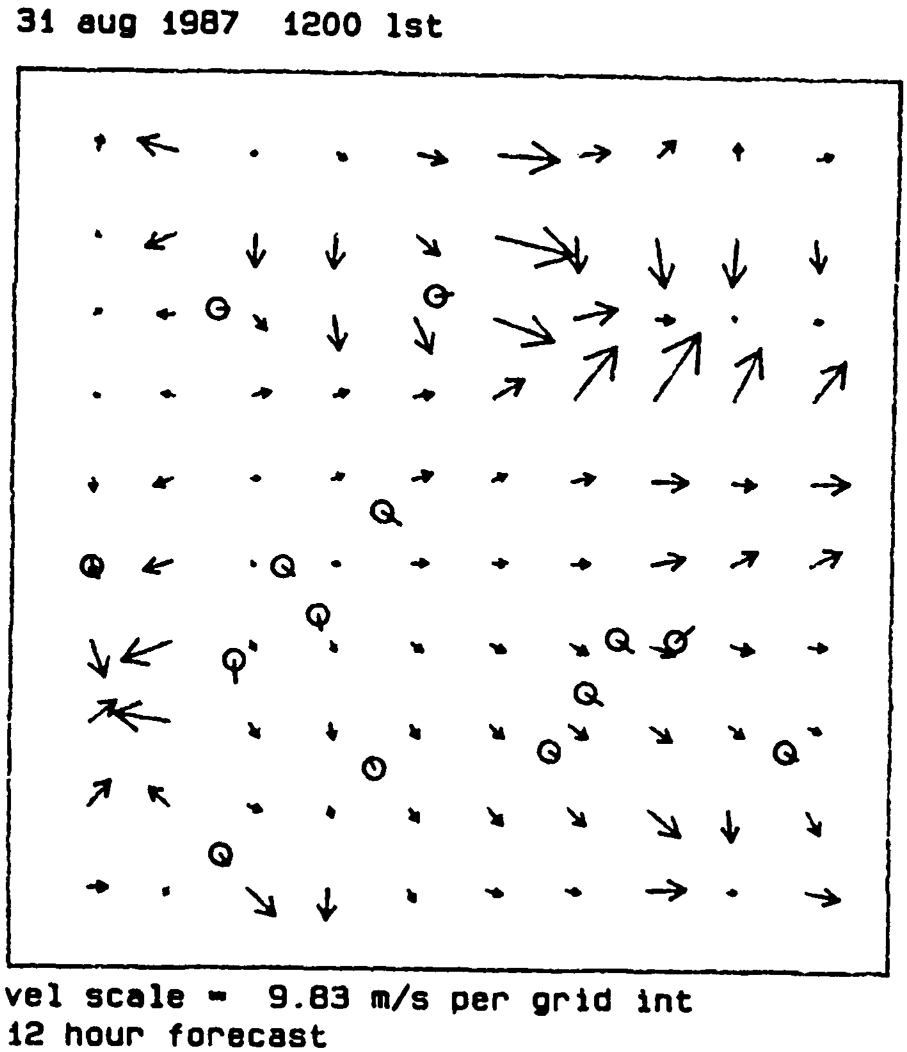


Figure 4. Wind Vectors Predicted by SIGMET for 1200 LST on 31 August 1987.

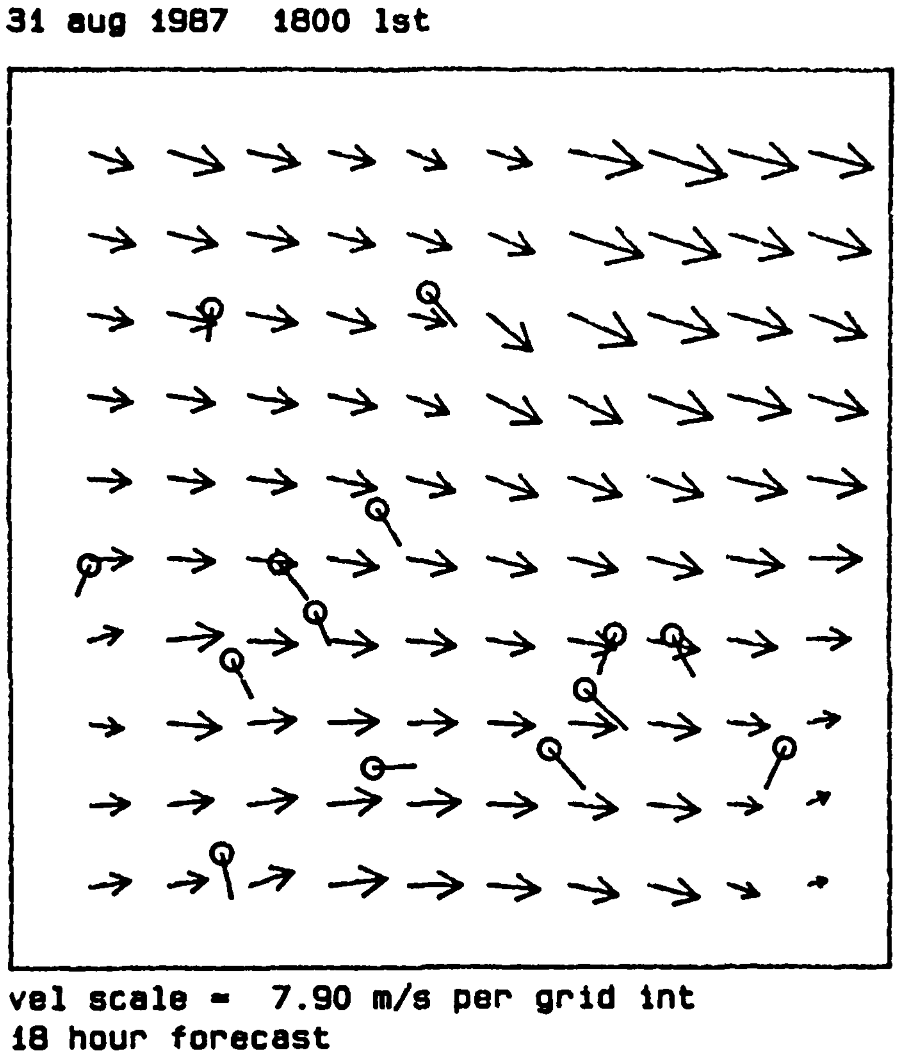


Figure 5. Wind Vectors Predicted by SIGMET for 1800 LST on 31 August 1987.

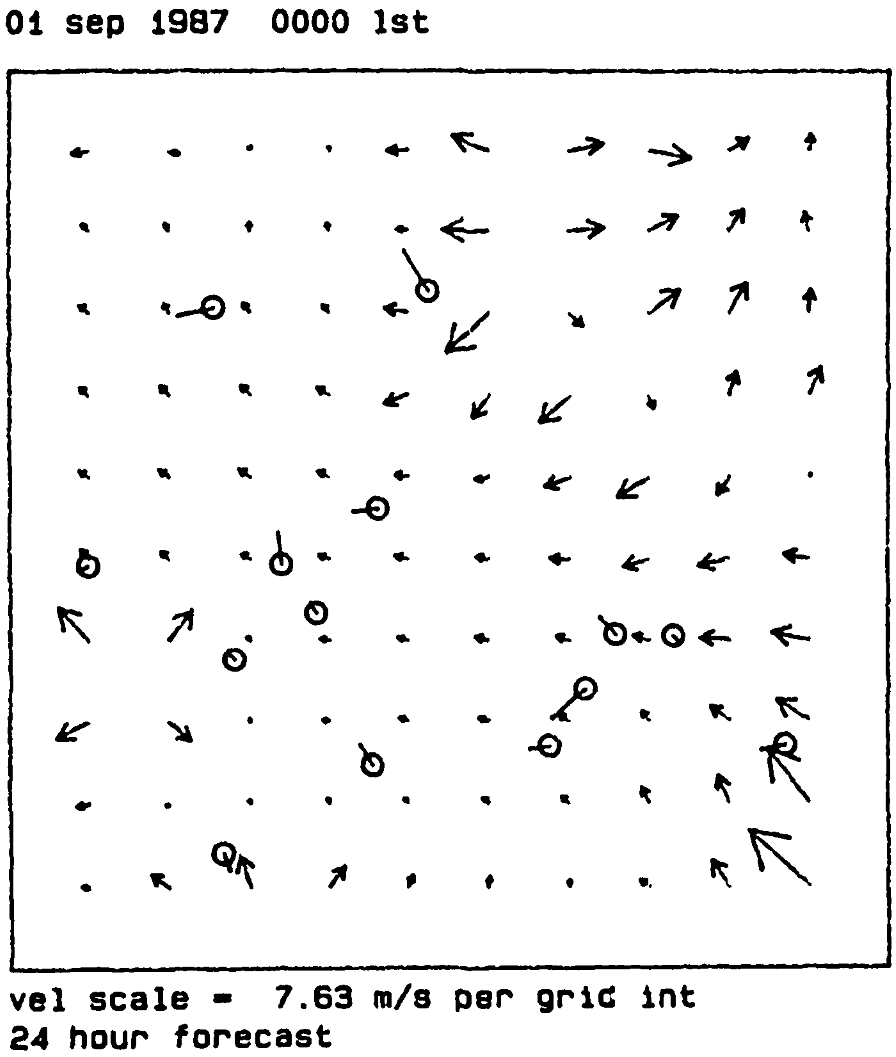


Figure 6. Wind Vectors Predicted by SIGMET for 0000 LST on 01 September 1987.

The effectiveness of the nested grid version of the BLAYER model was tested by comparing the model's predictions for the three cases summarized in Table 2. The meteorological inputs used in these runs were for the 31 August 1987 case discussed in the preceding subsection. All runs began at 0600 LST. The nested grid version of the BLAYER model used in the runs outlined in Table 2 did not incorporate all of the Part II model changes described in Subsection 2.1.2. Nevertheless, the general results should also be applicable to the current version. The 10-meter wind fields predicted at 1200 LST for Cases 1, 2, and 3 are shown in Figures 7, 8, and 9, respectively. Similarly, the 10-meter wind fields predicted at 1800 LST for the three cases are shown in Figures 10 through 12.

The BLAYER model results for Case 1, which used a large horizontal domain with a dense grid spacing, serve as the baseline for evaluating the results for the other cases. Comparison of Figure 7 with Figures 8 and 9 shows that Cases 2 and 3 both reproduce the baseline results reasonably well. For example, the maximum wind speeds for Cases 2 and 3 are within about 5 percent of the maximum wind speed for Case 1. However, although not readily evident from visual inspection, most of the Case 2 wind directions differ from the corresponding Case 1 wind directions by 5 to 10 degrees. After 12 hours of simulation time, comparison of Figure 10 with Figures 11 and 12 shows that the wind fields predicted for Cases 2 and 3 are in poor agreement with the Case 1 wind field. Significant differences in wind speed and direction are found over large portions of the grid.

It is not clear why the nested grid version of the BLAYER model did not perform better than the single grid version with only the small, inner grid. Possible explanations for the poor performance of the nested grid version include: (1) the large-scale solution is very sensitive to the horizontal resolution, (2) the boundary values for the inner grid are not adequately described by the interpolation of the large-scale results, and (3) small-scale motions in the inner grid may have a significant impact on the large-scale flow surrounding the inner domain. If the first explanation is correct, a nested grid version of the model is not feasible at DPG because of the complexity of the terrain. If the second and third explanations are correct, the problems might be solved by employing a two-way interactive nested grid model. Because the development of a two-way interactive model is much more difficult than the development of a one-way interactive model, no further attempts were made to develop or evaluate a nested grid version of the BLAYER model.

2.2.2.3 The HOTMAC Model

The version of the HOTMAC model that was modified by LANL for operational use at U.S. Army chemical storage depots was received by U.S. Army Nuclear and Chemical Agency (USANCA) in the spring of 1989. Although the modified version of the model was developed under contract to the Army, the model's availability for use by the Army initially was uncertain because of a copyright issue. The model is copyrighted by the Regents of the University of California, which operates LANL under contract to the Department of Energy (DOE), and the Regents have issued an exclusive license to the model's author. It was not until July 1989 that USANCA determined that the exclusive license applied only to commercial applications and did not restrict the Army's right to use the model. A second concern affecting USANCA's release of the HOTMAC model was the need to establish a configuration control group to control implementation, modification, and distribution of the model. USANCA subsequently proposed that this configuration control group should consist of technical representatives from DPG, ASL, and U.S. Army Chemical Research, Development and Engineering Center (CRDEC). USANCA distributed copies of the HOTMAC model's computer code to the proposed members of the configuration control group in September 1989. Because the HOTMAC model was not received until three weeks before the completion date for this study, there was no time to perform qualitative evaluations of the model. The lack of the user experience that is gained during qualitative tests may have placed the HOTMAC model at a disadvantage in the quantitative evaluation.

Table 2. Identification of Cases Used to Nest the Nested Grid Version of BLAYER.

Case	Model Version	Horizontal Domain		Horizontal Resolution (km)	Time Step (s)
		Type	Extent (km)		
1	Single Grid	Large	145 x 145	5.0	60
2	Single Grid	Small	95 x 95	5.0	60
3	Nested Grid				
		Large	145 x 145	14.5	120
		Inner	95 x 95	5.0	60

2.2.3 Quantitative Evaluation

Table 3 lists the historical cases used in the quantitative model evaluation. These cases consist of a summer day with a diurnal wind regime (31 August 1987), a winter day with snow cover and a diurnal wind regime (18 January 1989), a day when the available meteorological data suggest that DPG winds were determined by the interaction of synoptic-scale and mesoscale influences (23 February 1988), a day in late spring with a diurnal wind regime (17 May 1989), and a day in late spring (19 May 1989) when the available meteorological data indicate that there was a strong synoptic-scale forcing of DPG winds. (A diurnal wind regime consist of the nighttime drainage winds and daytime upslope winds that typically occur at DPG in the absence of strong synoptic-scale winds.)

The model simulations for the historical cases were for 24-hour periods beginning at midnight (0000) LST. Meteorological inputs for both the BLAYER and HOTMAC models were derived from rawinsonde (upper-air) soundings made at the Salt Lake City International Airport at 1700 LST on the afternoon preceding each test case. Although DPG soundings would have provided more representative meteorological inputs, DPG does not make soundings for forecast support because

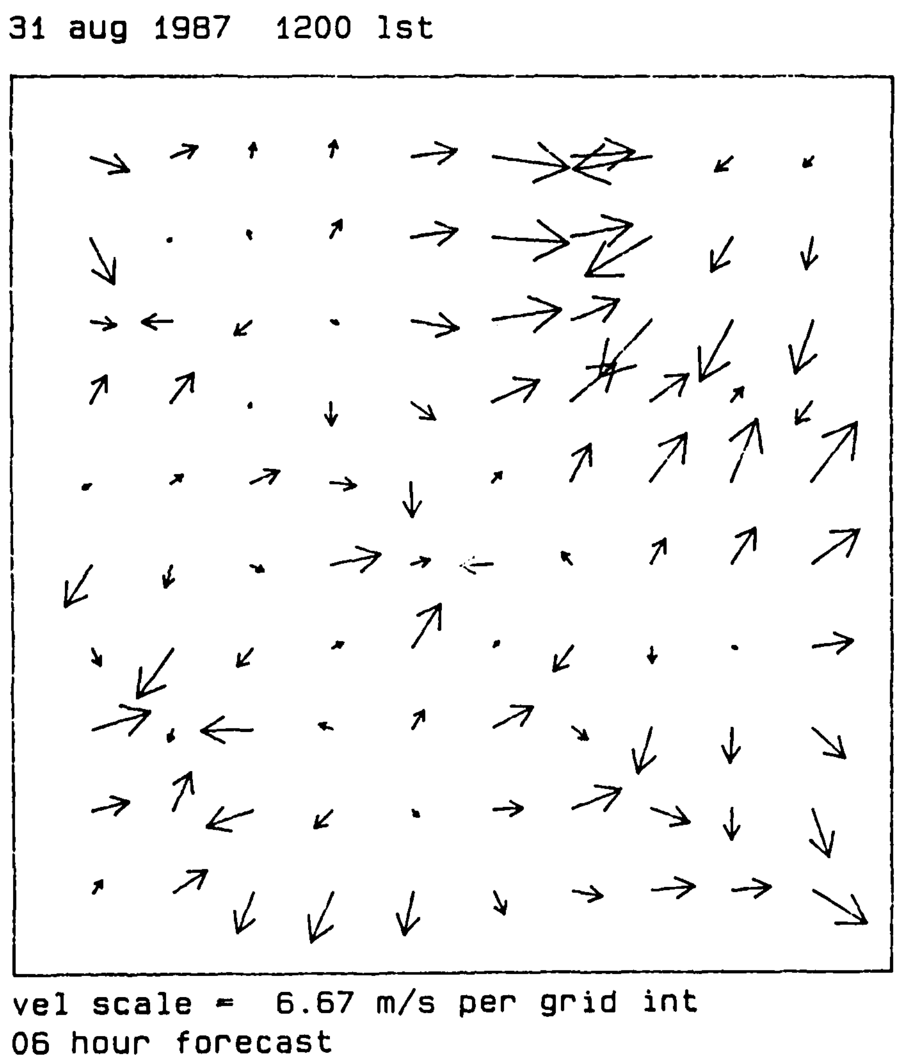


Figure 7. BLAYER 6-Hour Forecast for Case 1 in Table 2.

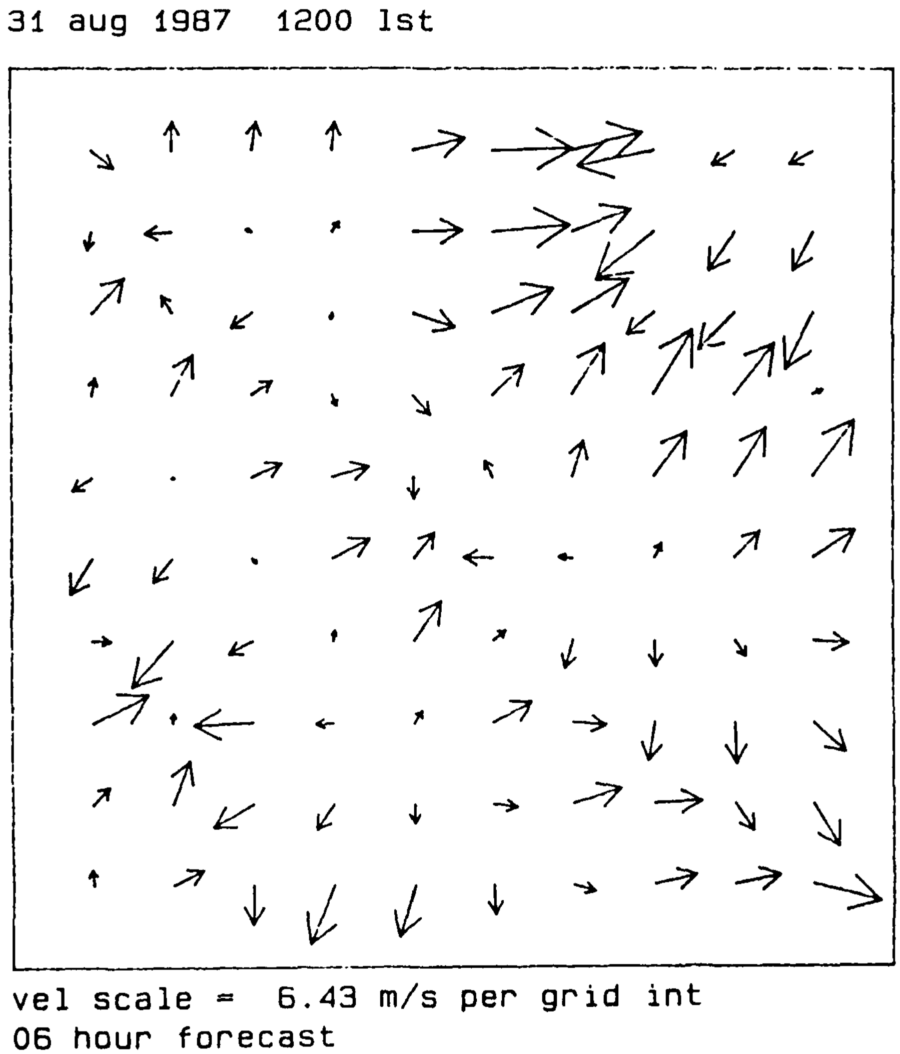


Figure 8. BLAYER 6-Hour Forecast for Case 2 in Table 2.

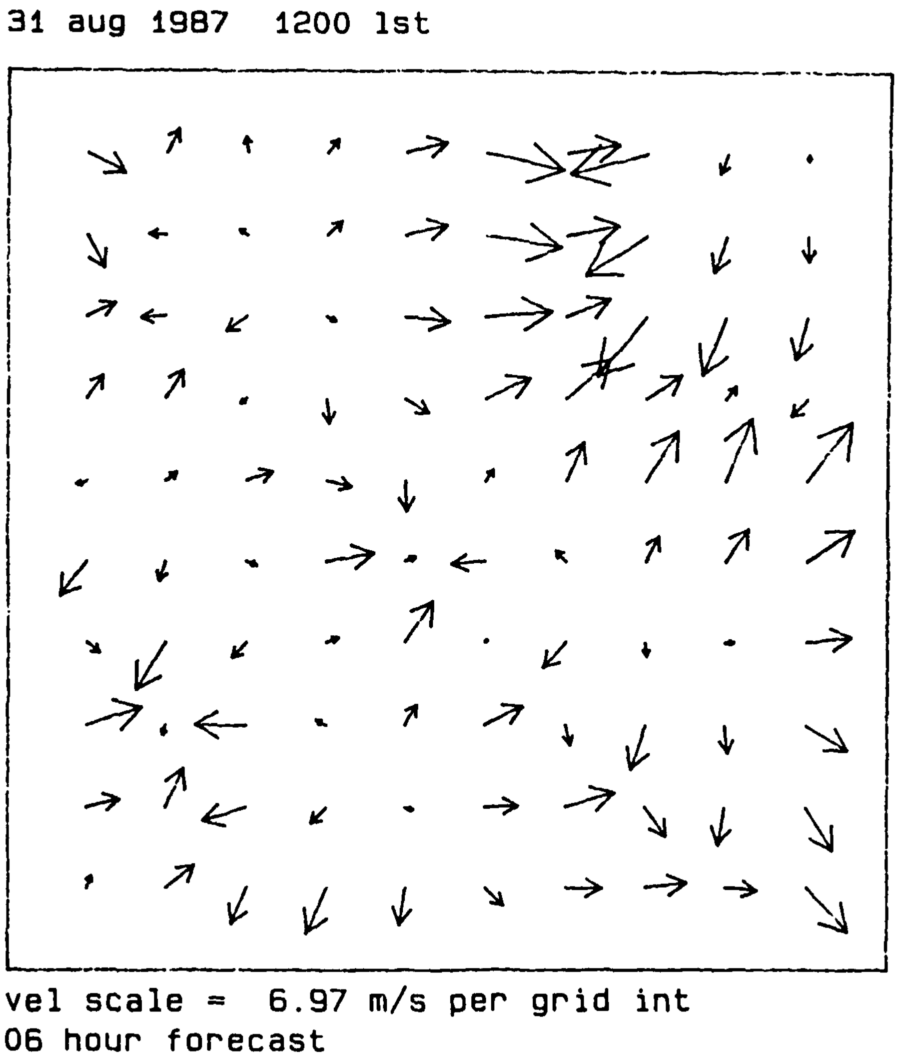


Figure 9. BLAYER 6-Hour Forecast for Case 3 in Table 2.

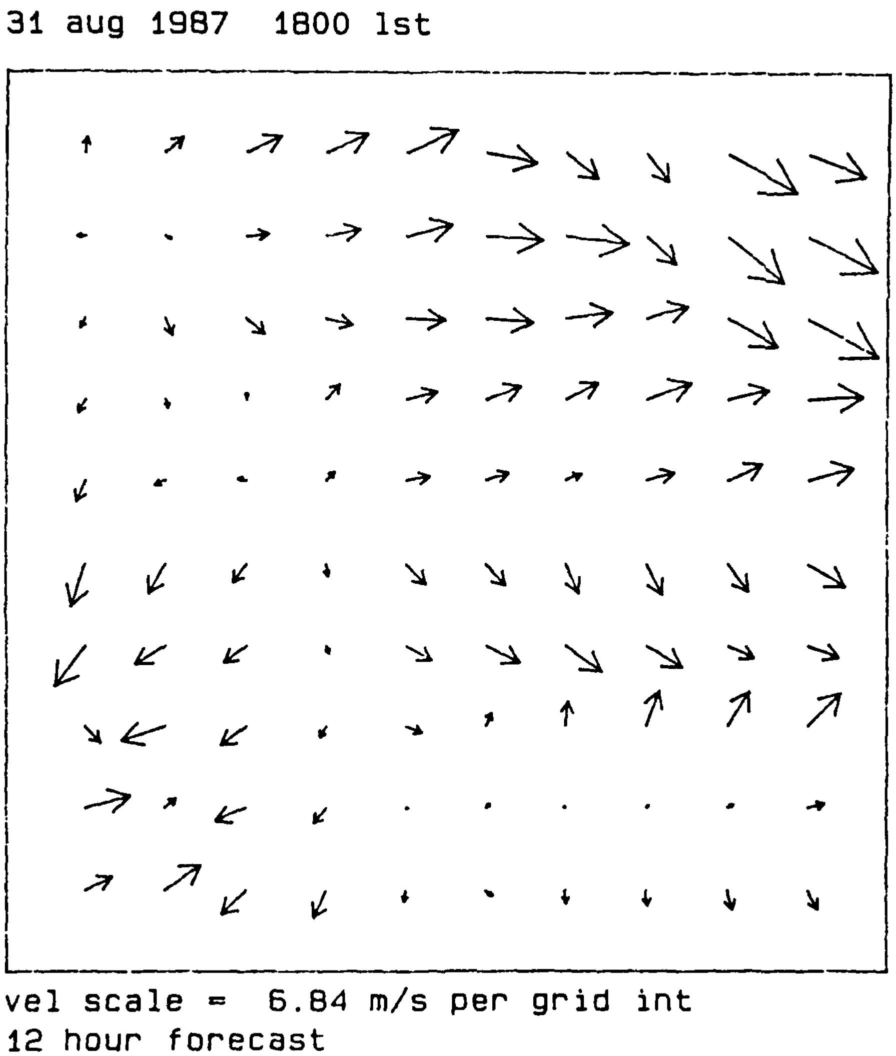
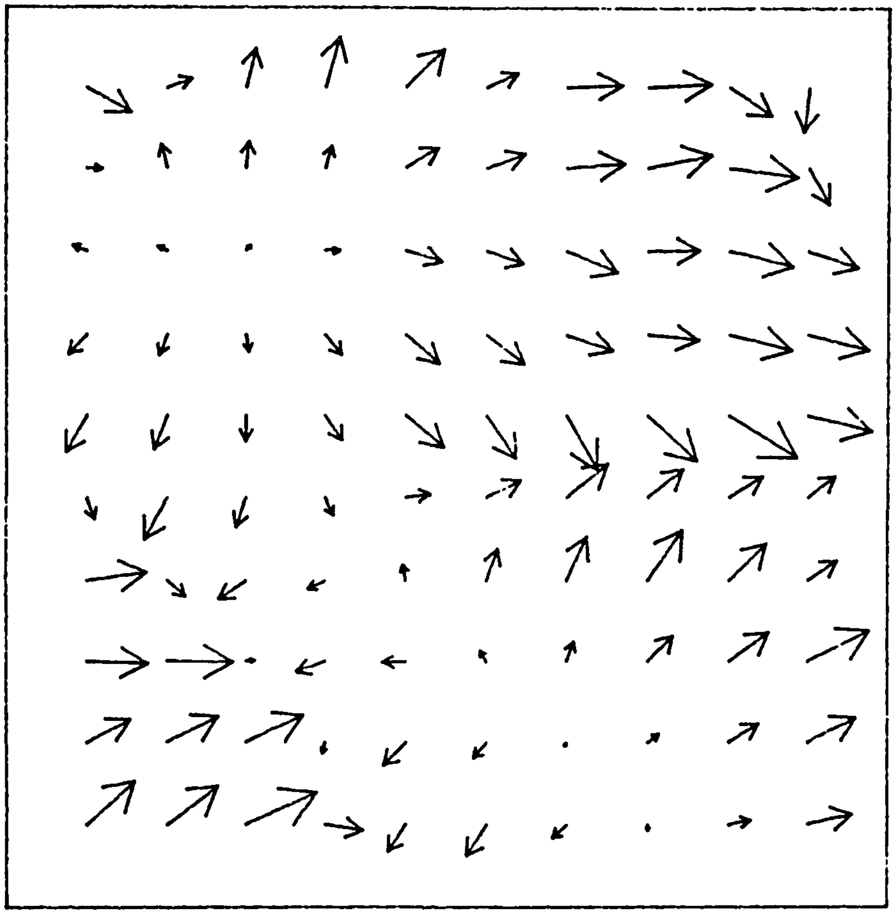


Figure 10. BLAYER 12-Hour Forecast for Case 1 in Table 2.

31 aug 1987 1800 lst



vel scale = 5.72 m/s per grid int
12 hour forecast

Figure 11. BLAYER 12-Hour Forecast for Case 2 in Table 2.

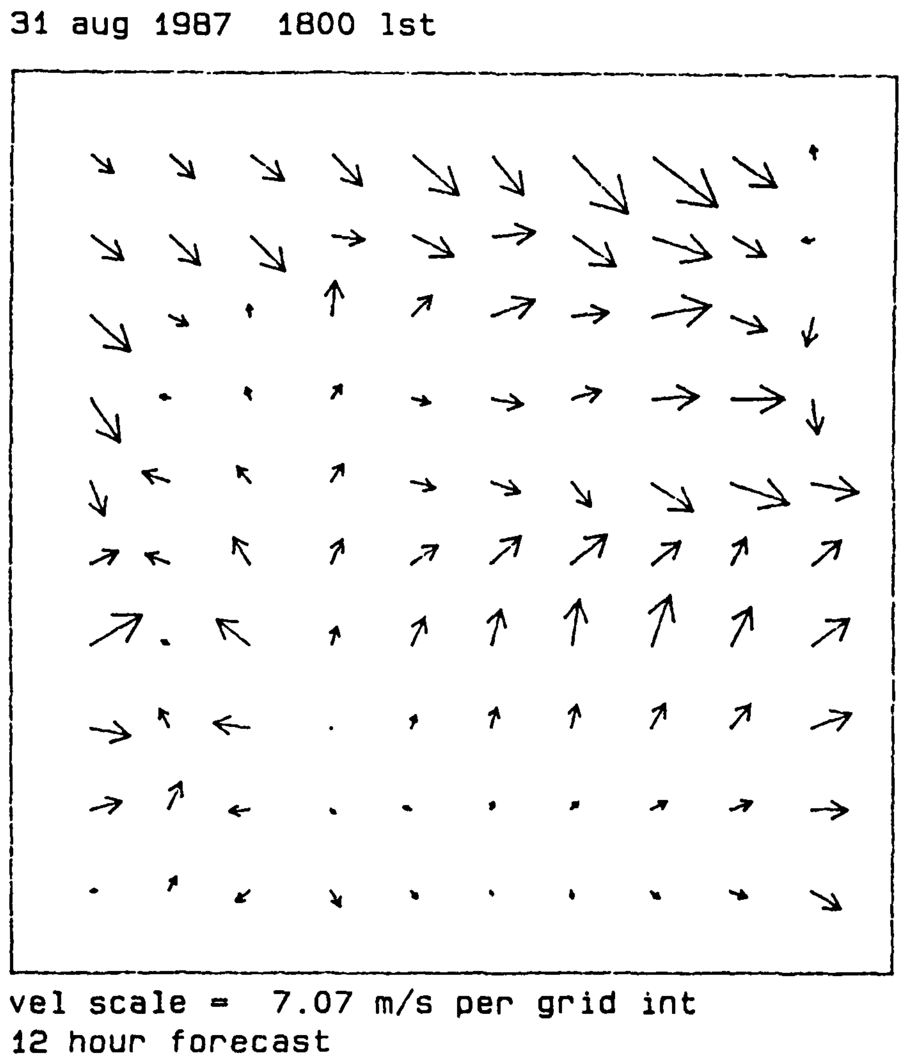


Figure 12. BLAYER 12-Hour Forecast for Case 3 in Table 2.

of budget limitations. Equivalent meteorological inputs were used with both models. (Note that the meteorological input requirements for the two models are not identical.) These inputs were based on the vertical meteorological structure summarized in Tables 4 and 5 for each historical case. Two sets of meteorological inputs were used for 31 August 1987, one based on the 30 August sounding at 1700 LST (Case 1) and one based on the 31 August sounding at 0500 LST (Case 2). Both sets were tried with the models because of the significant changes in synoptic-scale conditions indicated by the two soundings. The differences in model predictions for the two sets illustrate the types of differences that can be expected when a model's initial conditions are defined by an observation and a synoptic-scale forecast during a period of significant change in synoptic-scale conditions.

Table 3. Identification of Historical Cases.

Case(s)	Date	Meteorological Regime
1 & 2[a]	31 Aug 87	Summer Diurnal
3	23 Feb 88	Interaction of Synoptic & Local Influences
4 & 5[b]	18 Jan 89	Winter Diurnal with Snow Cover
6	17 May 89	Late Spring Diurnal
7	19 May 89	Strong Synoptic Forcing

[a]Cases differ in their initial conditions (see Tables 4 and 5).
[b]Case 4 assumes new snow and Case 5 assumes old snow (see Table 6).

The BLAYER and HOTMAC models were executed for the historical cases using surface characteristics defined by the inputs given in Table 6. As noted above, the ground was covered by snow on 18 January 1989. Because there is no way to determine whether the snow surface was "new snow" (clean) or "old snow" (soiled and crystallized), the model calculations were performed both ways. Note that the surface characteristics in Table 6 were assumed to be uniform over the computational domain. In a related methodology investigation, Astling (1989) has shown that the variations in surface characteristics at DPG can significantly affect local circulations.

The HOTMAC model has a unique "nudging" term (GNUDGE) in the equations of motion to (Yamada and Bunker, 1989, p. 545) "...guide the modeled winds in the layers above the ridge top toward the observed wind." According to the model documentation (Williams et al., 1989), the acceptable range for the GNUDGE parameter is from zero to five times the Coriolis parameter. With the proper combination of an initial wind profile and the GNUDGE parameter, HOTMAC can reproduce vertical wind shears that it could not otherwise resolve. Because there is little guidance available on how to specify GNUDGE when HOTMAC is used to predict wind fields, GNUDGE was set equal to zero to delete the effects of the nudging term.

Table 4. Winds at Standard Levels for the Historical Cases.

Case	Date	Time (MST)	Wind Direction (deg)/Wind Speed (m/s) SFC	850 mb	700 mb[a]	500 mb
1	30 Aug 87	1700	330/4.7	340/4.7	335/10.3	325/10.8
2	31 Aug 87	0500	140/4.1	150/3.1	045/3.1	045/2.6
3	22 Feb 88	1700	350/6.2	350/4.2	295/10.3	320/29.9
4	17 Jan 89	1700	330/3.6	330/2.1	300/10.3	345/17.0
5	17 Jan 89	1700	330/3.6	330/2.1	300/10.3	345/17.0
6	16 May 89	1700	340/4.7	345/4.7	310/4.1	335/6.2
7	18 May 89	1700	360/12.9	360/13.9	245/13.9	220/19.0

[a]Used as initial wind inputs.

The BLAYER and HOTMAC models were executed for the historical cases using a 145- by 145-kilometer grid with a 5-kilometer resolution. In each case, the time step for the BLAYER model was 30 seconds. The HOTMAC model internally calculates its time step. The maximum time step used by HOTMAC for the historical cases was 890 seconds. The 10-meter wind fields forecast by the BLAYER and HOTMAC models at 0600, 1200, 1800, and 0000 LST are shown in Appendix B. These plots, which are drawn to the same scale as Figure 2, also show the observed Mesonet winds.

Inspection of the wind field forecasts in Appendix B leads to several general conclusions about qualitative model performance. First, the wind fields predicted by HOTMAC are generally much smoother than those predicted by BLAYER. That is, the winds predicted by BLAYER show local topographic influences that are not evident in the HOTMAC results. However, these influences appear to be overemphasized during the day, and a grid resolution finer than the 5-kilometer resolution used in this study appears to be necessary for BLAYER to resolve them adequately. Both models show relative strengths and weaknesses for the cases modeled. BLAYER tends to perform best at night when there are drainage winds, while HOTMAC tends to perform best during the daytime when these are upslope winds. In general, BLAYER overestimates the magnitude of the flow at 10 meters and HOTMAC underestimates it.

The RMS difference between observations and predictions was selected as a quantitative measure for intercomparing the performance of the BLAYER and HOTMAC models. The RMS difference is a measure of absolute model accuracy that includes both the bias (systematic error) and the precision (random error). The RMS difference was selected for two reasons. First, absolute model accuracy is of scientific interest at this stage of the investigation. Second and

Table 5. Average Relative Humidities and Lapse Rates for the Historical Cases.

			Average Humidity (%)			Lapse Rate (°C/km)		
Case	Date	Time (MST)	850-700 mb	700-500 mb	850-500 mb	850-700 mb	700-500 mb	850-500 mb
1	30 Aug 87	1700	19	16	17	9.0	7.3	8.0
2	31 Aug 87	0500	12	35	25	7.3	7.9	7.7
3	22 Feb 88	1700	32	20	25	8.2	4.0	5.6
4	17 Jan 89	1700	42	29	35	3.4	4.2	3.9
5	17 Jan 89	1700	42	29	35	3.4	4.2	3.9
6	16 May 89	1700	54	42	47	7.9	6.8	7.2
7	18 May 89	1700	42	--[a]	--	8.0	--	--

[a]Missing Data.

Table 6. Summary of Surface Characteristics Assumed in the Model Calculations.

Surface Characteristic	Assumed Value: Soil	Old Snow	New Snow
Albedo	0.4	0.6	0.8
Emissivity	0.95	0.82	0.99
Specific Heat (J/kg/°C)	1675	419	209
Density (kg/m^3)	1780	300	200
Thermal Diffusivity (m^2/s)	2×10^{-7}	4×10^{-7}	2×10^{-7}

more importantly, because bias and precision are likely to vary with meteorological regime, one day per meteorological regime is too small a sample size to obtain reliable estimates of bias and precision. The RMS difference for the u (east-west) wind component is given by

$$\mathrm{RMS}(u) = \left[\frac{1}{N}\sum_{i=1}^{N}(u_{oi} - u_{pi})^2\right]^{1/2} \qquad (1)$$

where N is the sample size and u_{oi} and u_{pi} are the ith pair of observed and predicted u wind components. The RMS difference for the v (north-south) wind component is given by Equation (1) with v substituted for u. The model 10-meter wind predictions were interpolated to the locations of the Mesonet stations to obtain the u_{pi} and v_{pi}. As a relative index of model performance in predicting total horizontal winds, the "total" RMS difference was defined as

$$\mathrm{RMS}(T) = [\mathrm{RMS}(u)^2 + \mathrm{RMS}(v)^2]^{1/2} \qquad (2)$$

Tables 7 and 8 give the total RMS differences between observed and predicted winds by hour of the day for the BLAYER and HOTMAC models, respectively. The tables show that each model has its own diurnal trend that is similar for all of the meteorological regimes. BLAYER's total RMS difference tends to decrease from a maximum or secondary maximum at the start of the simulation period to a minimum between around 0600-0800 LST, increase to a secondary maximum or maximum around 1400-1600 LST, and then decrease throughout the remainder of the forecast period. The diurnal variation of HOTMAC's total RMS difference is not as pronounced as BLAYER's diurnal variation. HOTMAC's total RMS difference tends to decrease from a maximum during the first few hours after the start of the simulation to a minimum at about 0800-1200 LST and then slowly increase throughout the remainder of the forecast period. The wind field plots in Appendix B show that the tendency for both models to have low total RMS differences at the transition periods near sunrise and sunset are explained by the low magnitudes of the predicted and observed winds rather than by forecast skill. As illustrated by the total RMS differences for Cases 1 and 2, the BLAYER results are more sensitive to differences in the initial winds than the HOTMAC results. Similarly, the total RMS differences for Cases 4 and 5 show that the BLAYER results are more sensitive to differences in the initial surface conditions than the HOTMAC results. Overall, HOTMAC yields the smallest total RMS values except during the early morning hours when drainage winds are well established.

In summary, neither the BLAYER model nor the HOTMAC model established a clear superiority for predicting DPG test grid winds for all meteorological regimes and times of the day. HOTMAC achieved the best overall performance statistics, but could not resolve some of the local influences that can significantly affect test grid winds. On the other hand, BLAYER appeared to overestimate local influences, especially during the daytime hours. Also, the 5-kilometer grid resolution was too gross for BLAYER to resolve these influences. It is likely that a grid resolution on the order of 1 kilometer will be required to achieve adequate resolution of very localized (i.e., microscale) influences in the predictions of either model. This resolution can possibly be achieved through a nested grid or by using the mesoscale model's output as input to a mass-consistent diagnostic model such as VARYME. Finally, this evaluation study may not have fairly represented the potential of either the BLAYER or HOTMAC model. As examples, horizontal variations of surface characteristics such as albedo were not considered with either model and HOTMAC's GNUDGE option was not used. Also, the Mesonet wind measurements with which the model predictions were compared reflect microscale influences that the models do not consider.

Table 7. Total RMS Differences Between Predicted and Measured Winds by Time for the BLAYER Model.

Time (LST)	Total RMS Difference (m/s)						
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
0100	6.7	3.2	5.6	5.5	5.3	4.3	10.1
0200	4.9	3.1	4.9	4.1	4.4	3.5	9.6
0300	3.6	2.7	4.6	3.3	4.1	3.0	9.1
0400	4.0	2.9	4.5	3.0	3.4	2.4	8.0
0500	4.0	2.8	4.6	2.9	3.0	1.8	6.8
0600	4.0	2.6	3.9	2.9	2.8	1.8	5.1
0700	3.7	2.2	3.5	2.7	2.3	1.8	5.4
0800	2.8	1.9	2.7	3.3	2.5	1.5	6.4
0900	2.7	1.9	1.8	2.2	2.9	1.2	5.1
1000	2.7	1.7	1.2	1.9	3.1	1.3	5.1
1100	4.2	1.8	1.6	2.6	4.5	1.5	6.3
1200	5.7	2.0	2.7	2.1	4.7	3.2	6.1
1300	4.5	2.1	3.7	3.1	6.2	3.7	7.4
1400	5.2	3.9	5.9	3.6	6.6	5.8	7.5
1500	6.2	4.2	7.1	3.4	6.5	7.6	7.6
1600	5.8	4.1	7.4	3.9	6.6	9.4	8.2
1700	5.1	3.9	6.4	3.7	6.1	9.9	9.0
1800	5.0	5.6	4.8	3.5	5.4	9.8	9.0
1900	5.1	6.4	4.6	3.0	5.1	8.2	8.8
2000	4.7	6.7	5.5	3.1	4.5	7.7	8.9
2100	4.8	5.6	5.3	3.0	3.6	6.9	7.1
2200	3.5	4.6	5.1	2.3	3.0	6.1	5.7
2300	4.7	3.9	4.3	2.8	3.2	5.7	5.8
0000	5.0	3.7	3.6	3.9	3.8	6.4	5.5

Table 8. Total RMS Differences Between Predicted and Measured Winds by Time for the HOTMAC Model.

	Total RMS Difference (m/s)						
Time (LST)	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
0100	4.8	3.9	4.9	4.6	4.3	4.6	8.6
0200	4.0	3.2	4.7	5.5	4.8	4.2	7.2
0300	3.8	2.9	4.2	6.3	5.2	4.4	6.5
0400	4.0	2.8	4.1	5.7	4.7	3.4	5.4
0500	3.7	3.2	3.8	6.0	4.9	3.4	5.9
0600	3.4	2.9	3.2	5.3	4.5	3.3	4.9
0700	3.2	3.1	2.9	4.7	4.0	3.1	5.0
0800	2.3	2.2	2.3	4.3	4.0	1.8	5.9
0900	2.1	1.7	2.1	3.8	3.7	1.6	5.7
1000	1.9	2.1	1.5	3.5	3.0	1.6	4.5
1100	2.0	2.0	1.6	2.7	2.2	1.3	4.5
1200	2.0	2.2	2.1	2.5	3.4	2.3	4.0
1300	2.3	2.2	2.8	2.7	4.0	2.7	4.4
1400	2.3	2.9	2.6	2.9	3.9	2.8	3.6
1500	2.5	3.2	2.8	3.2	3.4	3.0	3.9
1600	3.2	4.1	3.3	2.5	3.4	3.2	3.7
1700	3.0	3.7	3.1	2.7	3.4	4.2	3.8
1800	2.8	3.1	3.4	2.7	3.2	5.1	3.8
1900	3.0	2.4	3.5	3.1	3.6	5.8	4.1
2000	4.1	3.4	4.6	3.7	4.2	5.2	5.2
2100	4.3	4.0	5.0	3.6	4.5	5.5	5.0
2200	4.0	4.5	4.7	3.2	4.1	5.9	4.1
2300	4.2	4.0	3.9	3.0	4.6	6.1	4.5
0000	4.0	3.6	4.0	3.3	5.3	6.1	4.0

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SECTION 3. APPENDICES

APPENDIX A

METHODOLOGY INVESTIGATION PROPOSAL AND DIRECTIVE

1. TITLE. Transport and Dispersion Model Hierarchy, Part II.

2. INSTALLATION/FIELD OPERATING ACTIVITY. U.S. Army Dugway Proving Ground, Dugway, UT 84022-5000.

3. PRINCIPAL INVESTIGATOR. Mr. James F. Bowers, Meteorology Division, STEDP-MT-M, Autovon 789-5101, <gross@dugway-emh2.army.mil>.

4. BACKGROUND. During Part I (FY88), several multiscale wind field models with the potential for predicting DPG test grid winds 24 to 36 hours in advance were acquired and implemented on a DPG computer system. The models are undocumented and very complex.

5. PROBLEM. It was necessary to devote the entire Part I effort to learning how to run the models. Also, completion of one of the candidate models was delayed from October 1987 until February 1989 or later. Consequently, DPG was unable to select the optimum model for use in predicting DPG test grid winds.

6. OBJECTIVE. Select the multiscale wind field model most suitable for predicting DPG test grid winds by comparing model predictions with Mesonet wind measurements for selected historical cases.

7. MISSION AREAS SUPPORTED. All field tests conducted at DPG will benefit, including mission areas such as combat support (NBC detection/warning, smoke/obscurants, etc.) and fire support (MLRS, etc.).

8. PROCEDURES

a. Compile DPG meteorological data sets for selected historical cases (January 1989).

b. Acquire the HOTMAC model from Los Alamos National Laboratory and implement the model on a DPG computer system (March 1989).

c. Compare predicted wind fields with Mesonet wind measurements for the historical cases (June 1989).

d. Investigate ways to improve model performance by changing computational domain, smoothing terrain, using nonuniform soil capacitance and/or albedo, etc. (August 1989).

e. Based on the results of Tasks c and d, select the optimum modeling approach for further adaptation (September 1989).

9. JUSTIFICATION/IMPACT. Field test activities at DPG, especially simulant and smoke/obscurants tests, are significantly affected by test grid winds. In many cases, tests are designed to be conducted under specific meteorological conditions, including wind speed and wind direction. This methodology investigation is intended to provide DPG with an operational model for forecasting local circulations up to 24 hours in advance. It differs from related activities in another ongoing investigation (Numerical Modeling of Test Grid Winds) in that the emphasis is on the adaptation for immediate operational use of a modeling system developed elsewhere rather than on the development of a model to account for the unique aspects of DPG's complex terrain, surface

roughness, and surface thermal characteristics. It is expected that each of the two methodology investigations will ultimately benefit from the other's results. If this investigation is not funded, near-term improvements in test grid wind forecasts are unlikely, especially during periods when mesoscale rather than synoptic scale effects are dominant. It is difficult to quantify the dollar savings that result from improved test grid wind forecasts. However, even a small reduction in the number of test days attributable to improved planning, design, and operational test decisions will result in substantial cost savings.

10. DOLLAR SAVINGS. NA.

11. RESOURCES.

a. Financial.

	Dollars (Thousands) FY89	
	In-House	Out-of-House
Personnel Compensation	20.0	
Contractual Support		25.0
Subtotals	20.00	25.0
FY Total	45.0	

b. Explanation of Cost Categories.

(1) Personnel Compensation. Compensation for federal civilian employees assigned to the methodology investigation.

(2) Contractual Support. This investigation will be a collaborative effort by personnel from the DPG Meteorology Division and the DPG meteorological support contractor. The contractor will participate in all phases of the study, with primary responsibility for computer software support.

c. Obligation Plan.

FQ	1	2	3	4	TOTAL
Obligation Rate (Thousands)	5.0	30.0	5.0	5.0	45.0

d. Man-Hours Required. Approximately 870 in-house direct labor hours and 550 contract direct labor hours will be required to complete this investigation.

12. ASSOCIATION WITH TOP PROGRAM.

a. No TOPs will be revised as a result of this investigation.

b. No new TOPs are contemplated.

13. AUTHENTICATION.

DEPARTMENT OF THE ARMY
HEADQUARTERS, U.S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005-5055

REPLY TO
ATTENTION OF

2 6 SEP 1988

AMSTE-TC-M (70-10p)

MEMORANDUM FOR: Commander, U.S. Army Dugway Proving Ground, ATTN: STEDP-MT-A, Dugway, UT 84022-5202

SUBJECT: FY 89 RDTE Methodology Improvement Program Grant

1. This memorandum advises that grants have been made for the investigations listed in enclosure 1 under the TECOM Methodology Improvement Program 1W665702D628.

2. The MIPs submitted in the FY 89-95 SOLID MIND are the basis for headquarters approval of the investigations.

3. Special instructions:

a. Although it is expected that literature searches were conducted prior to submitting a methodology investigation proposal (MIP) to ensure that the MIP did not duplicate work already performed, further searches should be made prior to investigation initiation to ensure that recent work performed by others will not change or obviate the need for the investigation about to begin.

b. All reporting, including final technical reports prepared by contractors, will be in consonance with paragraph 2-6 of the reference. The final report will be submitted to this headquarters, ATTN: AMSTE-TC-M, in consonance with Test Event 570/580. Each project shall be completed in FY 89 as reflected in the scheduling.

c. Recommendations for new TOPs or revisions to existing TOPs will be included as part of the recommendation section of the final technical report. Final decision on the scope of the TOP effort will be made by this headquarters as part of the final technical report approval process.

d. The addressee will determine whether any classified information is involved, and will assure that proper security measures are taken when appropriate. All OPSEC guidance will be followed strictly during each investigation.

e. Prior to investigation execution, the test activity will verify that no safety or potential health hazards to humans participating in testing exist. If safety or health hazards do exist, the test activity will provide a safety/health hazards assessment statement to this headquarters prior to investigation initiation.

f. Environmental documentation for support tests or special studies is the responsibility of the test activity and will be accomplished prior to initiation of the investigation.

g. Upon receipt of this grant notification, test milestone schedules as established in TRMS II data base will be reviewed in light of other known work load and projected available resources. If rescheduling is necessary and the sponsor nonconcurs, a letter citing particulars, together with recommendations, will be forwarded to Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-TC-M, with an information copy to AMSTE-TA-O, no later than 15 calendar days from the date of this memorandum. Reschedules concurred in by the sponsor can be entered directly along with a properly coded narrative by your installation/test activity.

h. All work shall be performed such that energy conservation is considered throughout the effort.

i. FY 89 RDTE funds authorized for the investigations are listed on enclosure 1. GOA Form 1006 will be forwarded by the TECOM Resource Management Directorate. A cost estimate shall be submitted within 30 days following receipt of this grant notification.

4. Reference Draft TECOM Regulation 70-12, dated 27 June 1988, TECOM Methodology Improvement and Standardization Programs.

5. Point of contact, this headquarters, is Mr. James Piro, AMSTE-TC-M, amstetcm@apg-4.apg.army.mil, AUTOVON 298-2170/3677.

FOR THE COMMANDER:

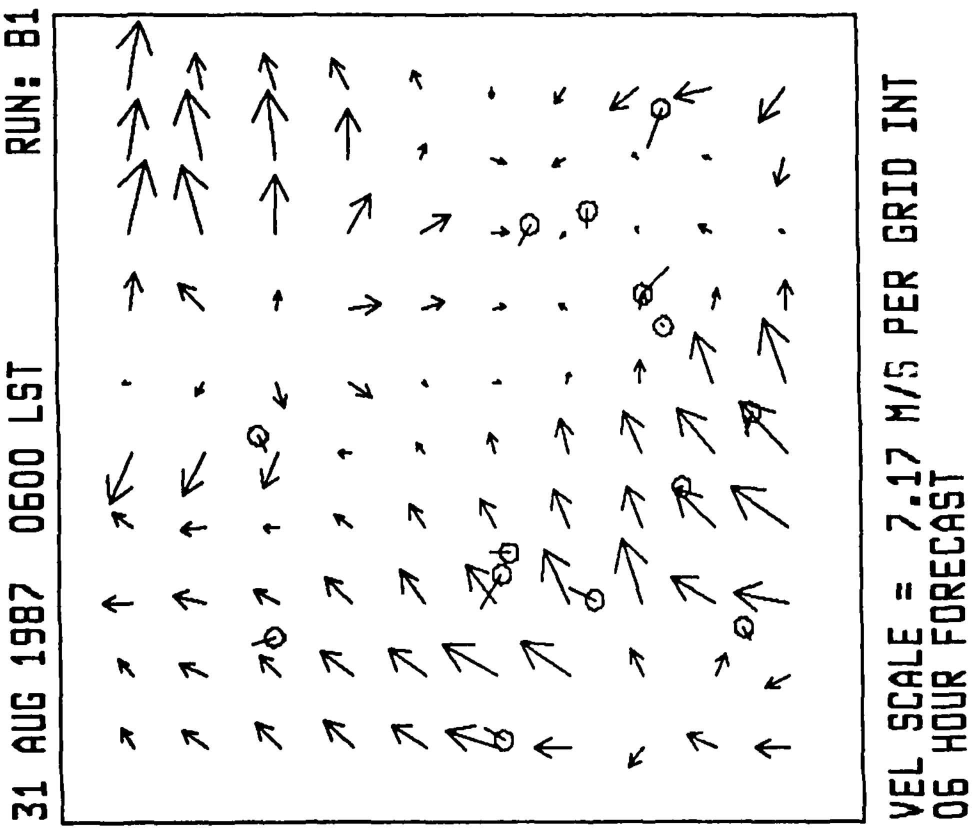
Grover H. Shelton

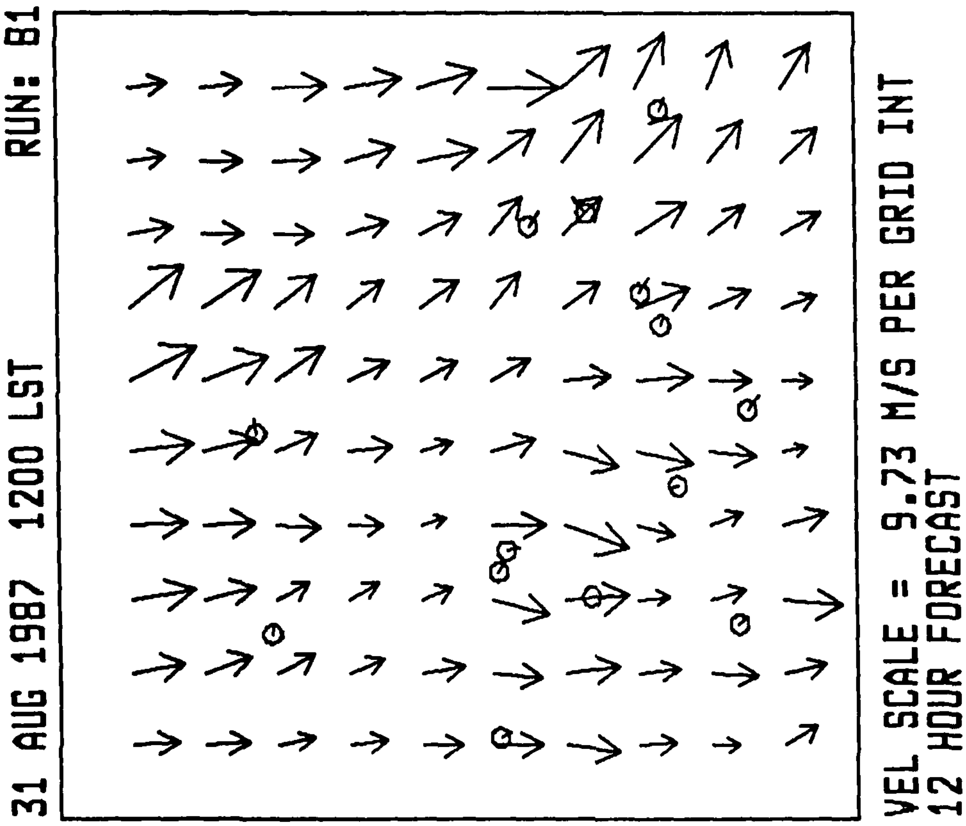
Encl

GROVER H. SHELTON
Chief, Meth Imprv Div
Directorate for Technology

APPENDIX B. FORECAST WIND FIELDS

This appendix contains figures illustrating the 10-meter wind fields forecast by the BLAYER and HOTMAC models at 0600, 1200, 1800, and 0000 LST for the historical cases identified in Table 3. The date of the case, time of the forecast, and run number are shown at the top of each figure. The run number consists of a letter (B for BLAYER and H for HOTMAC) followed by the case number from Table 3. See Subsection 2.2.2.1 for a discussion of how to interpret the figures in this appendix.


31 AUG 1987 0600 LST RUN: B1
VEL SCALE = 7.17 M/S PER GRID INT
06 HOUR FORECAST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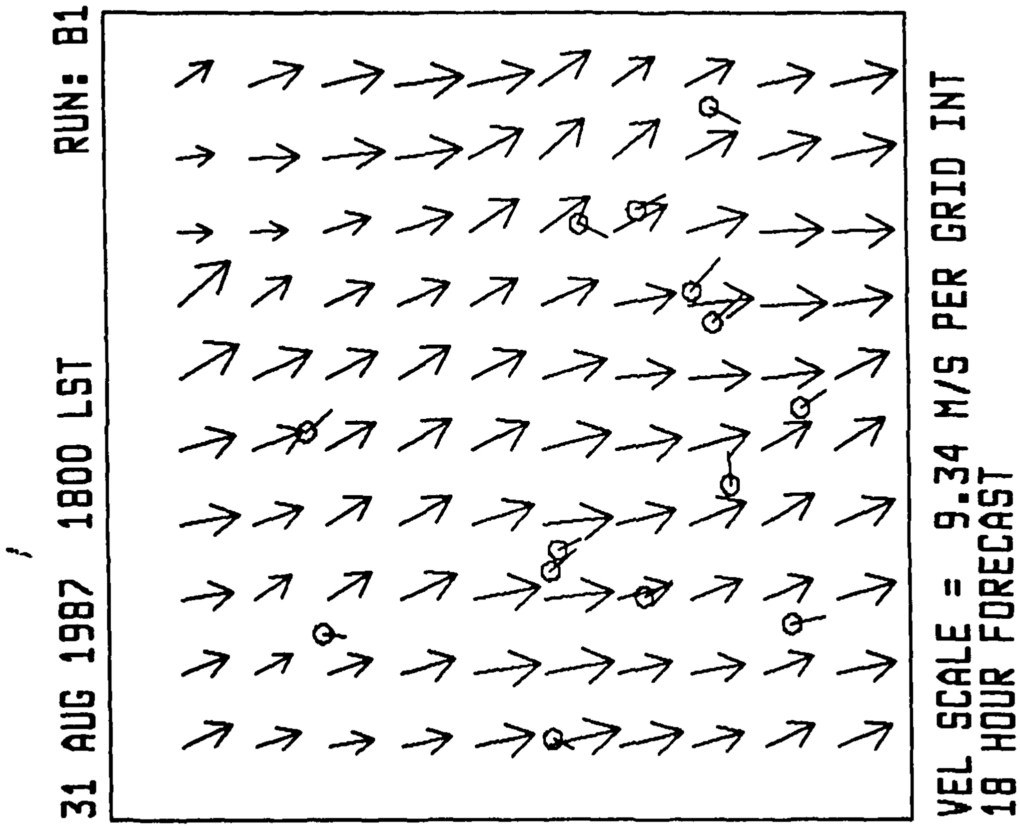
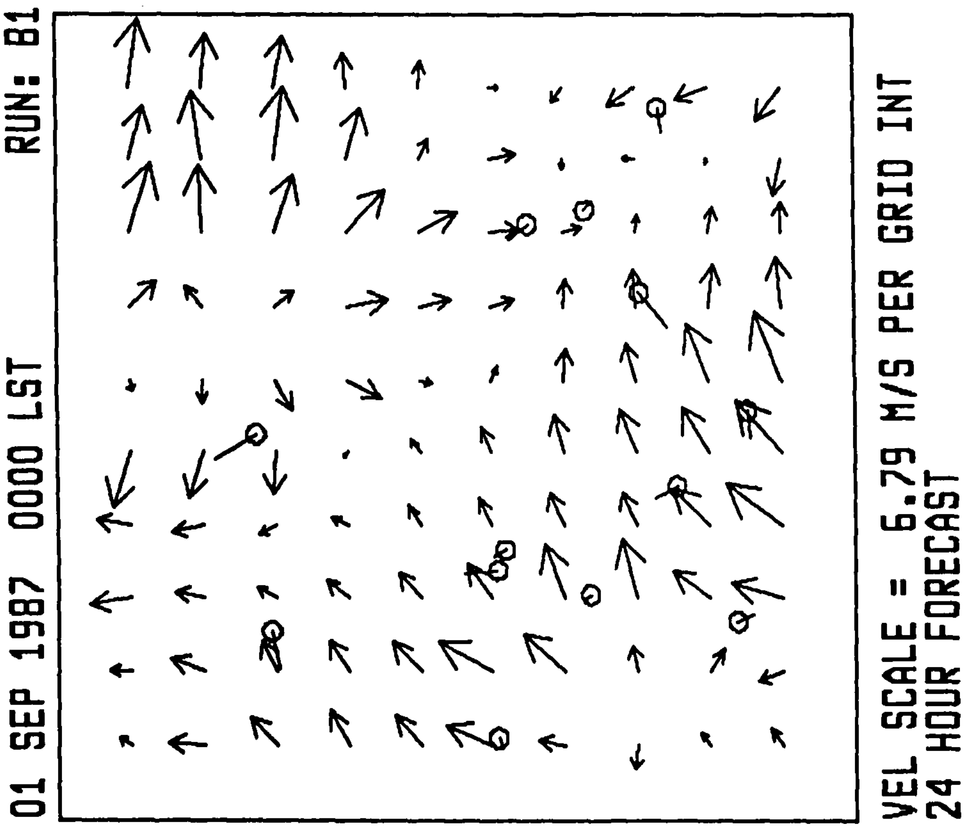
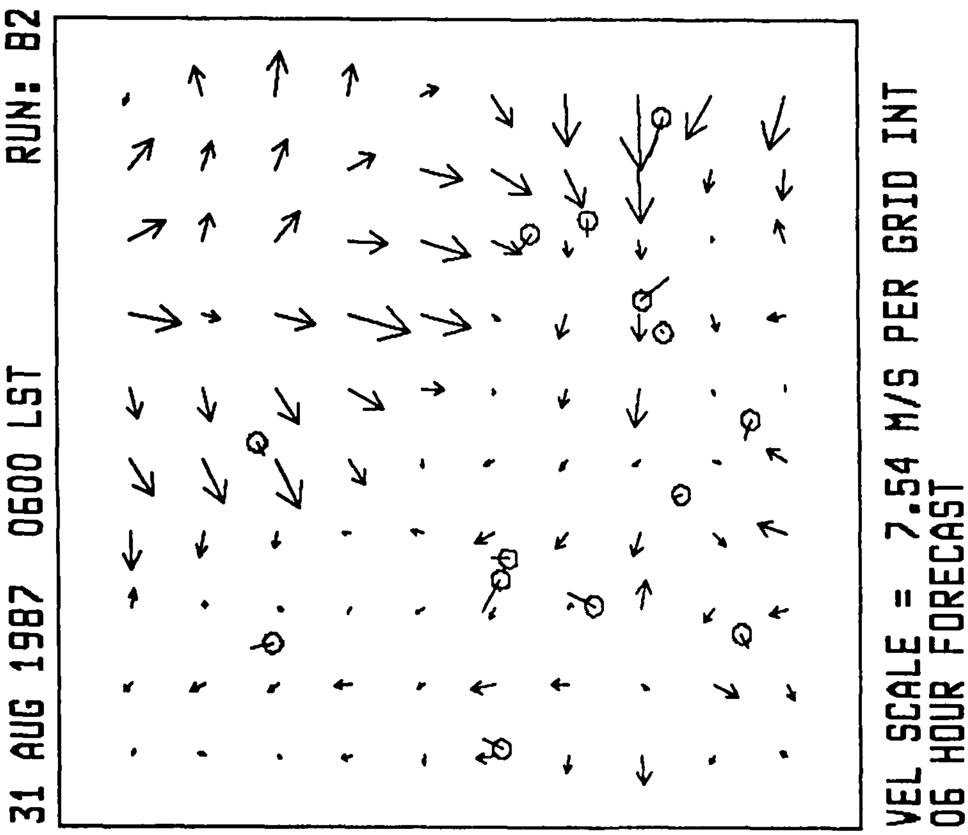

31 AUG 1987 1800 LST
RUN: B1
VEL SCALE = 9.34 M/S PER GRID INT
18 HOUR FORECAST


01 SEP 1987 0000 LST
RUN: B1
VEL SCALE = 6.79 M/S PER GRID INT
24 HOUR FORECAST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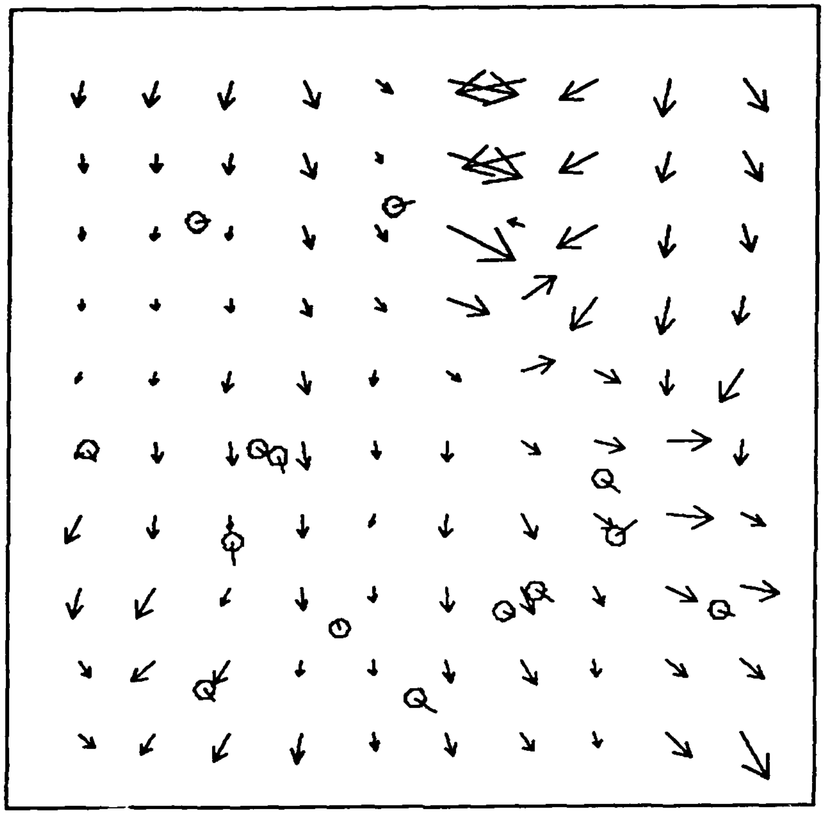
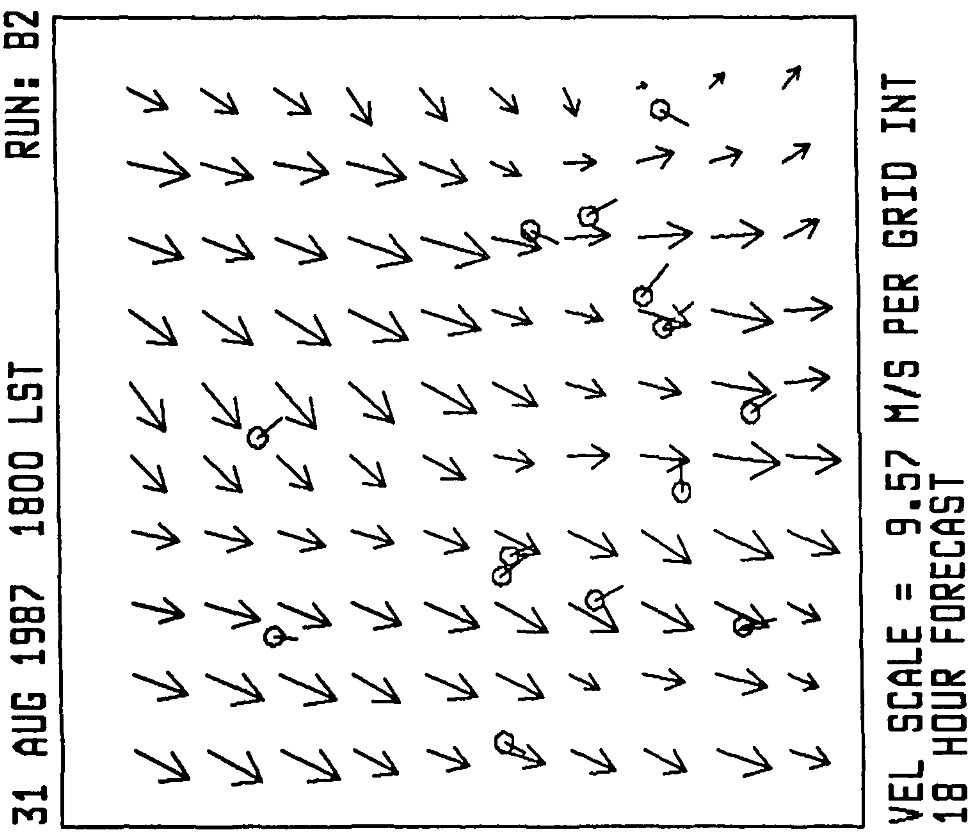
RUN: B2
VEL SCALE = 7.54 M/S PER GRID INT
06 HOUR FORECAST

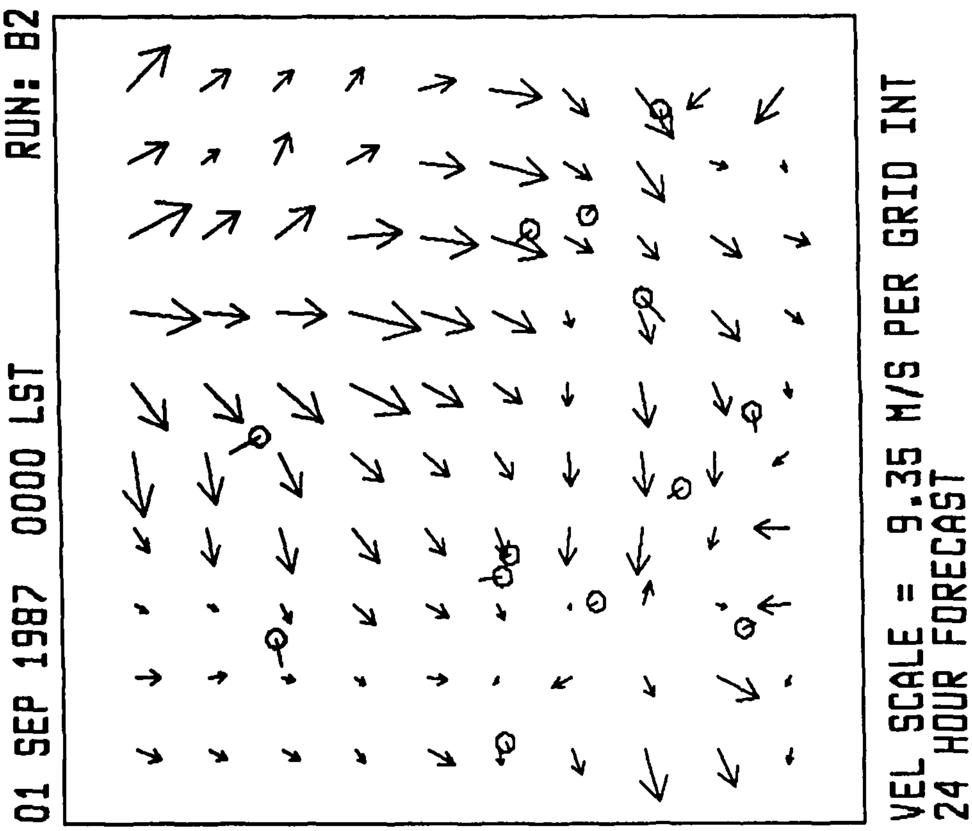
31 AUG 1987 1200 LST RUN: B2

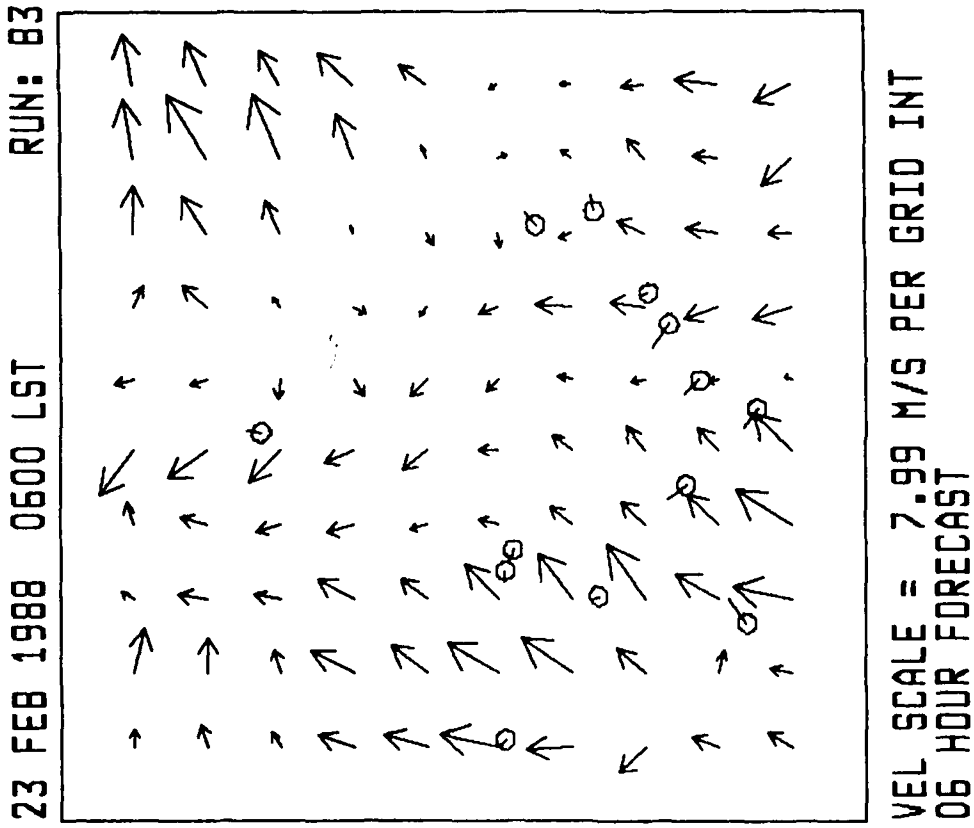


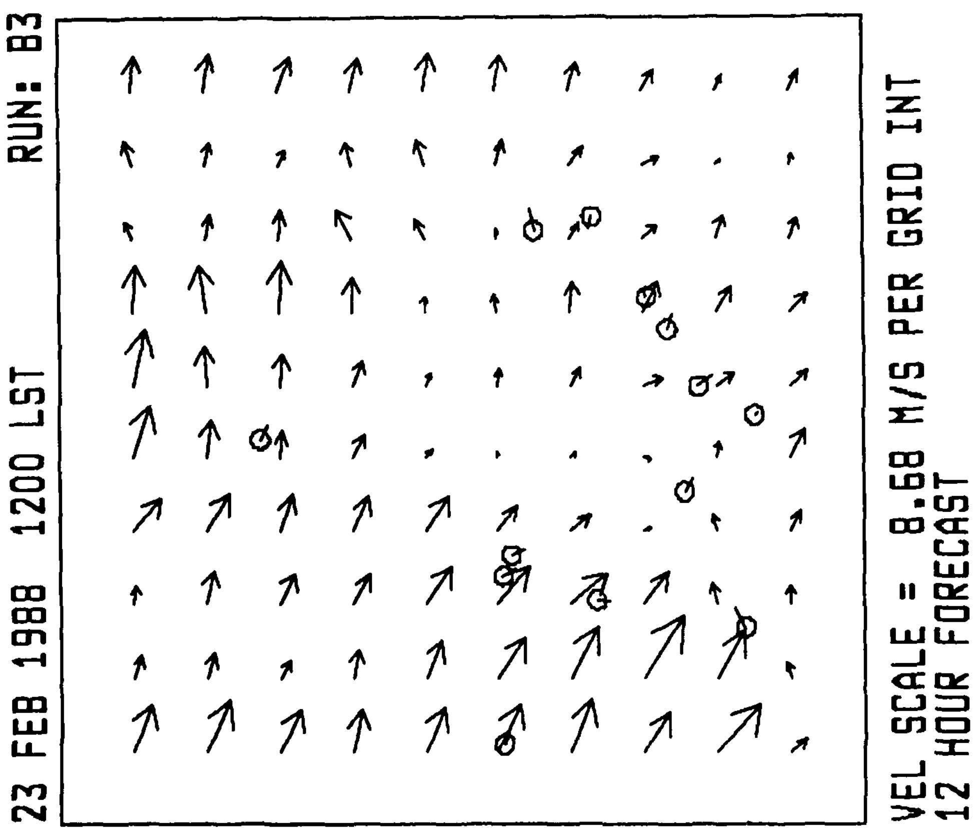
VEL SCALE = 7.94 M/S PER GRID INT
12 HOUR FORECAST

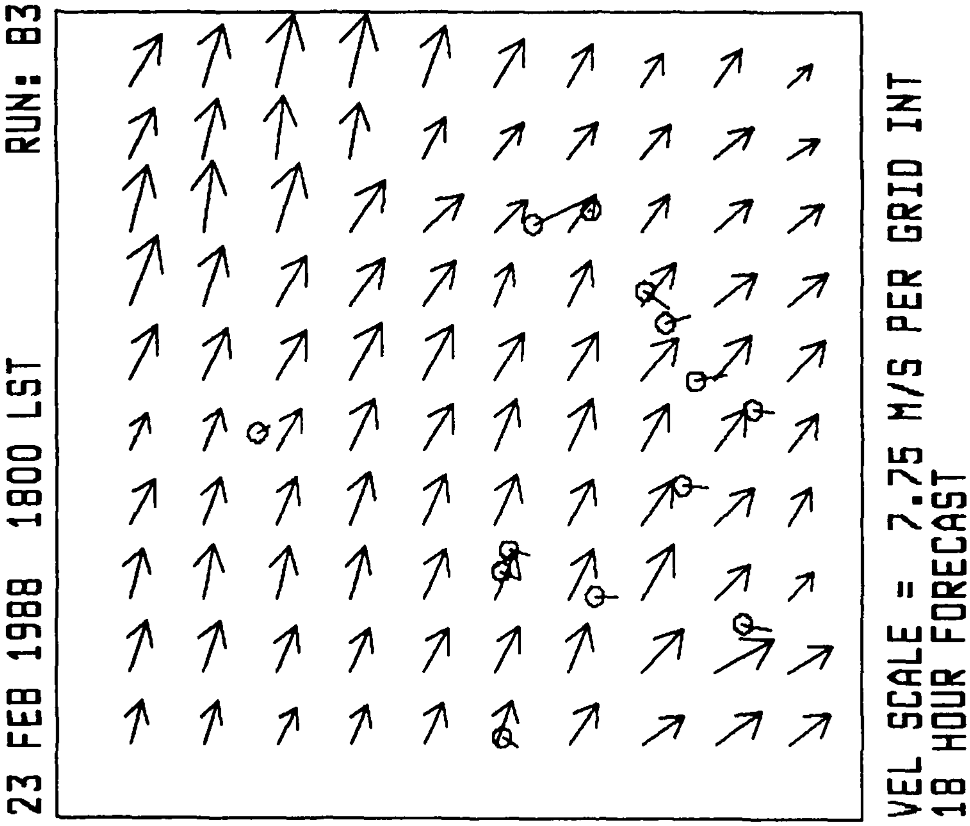


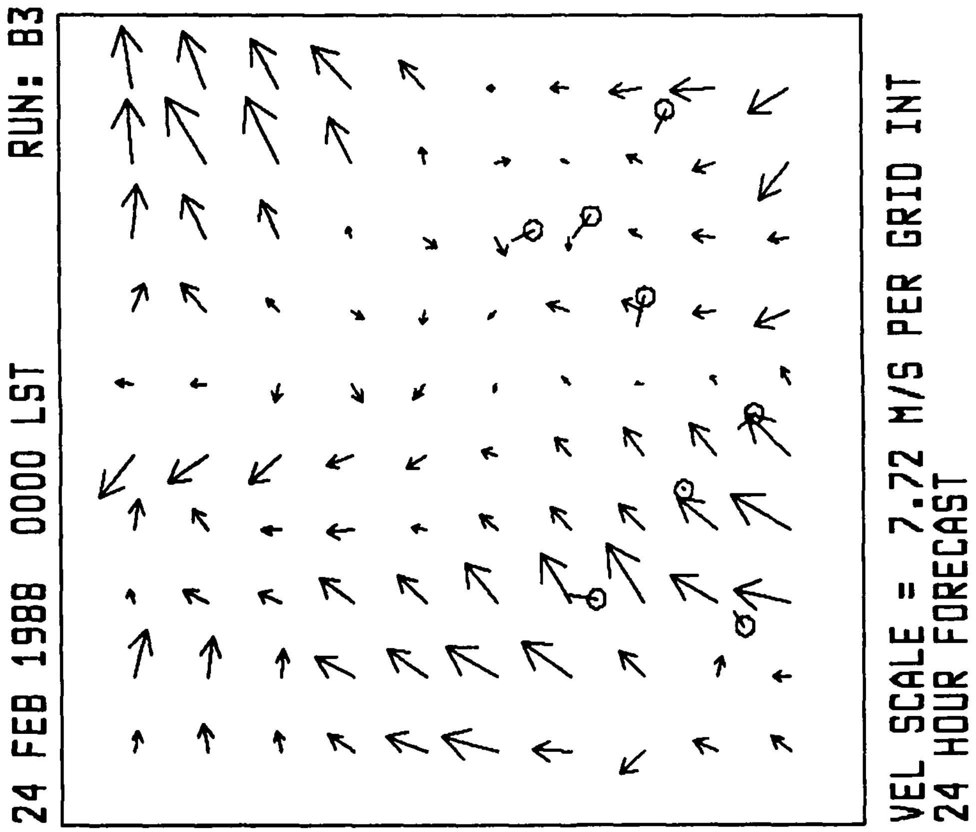
31 AUG 1987 1800 LST
RUN: B2
VEL SCALE = 9.57 M/S PER GRID INT
18 HOUR FORECAST

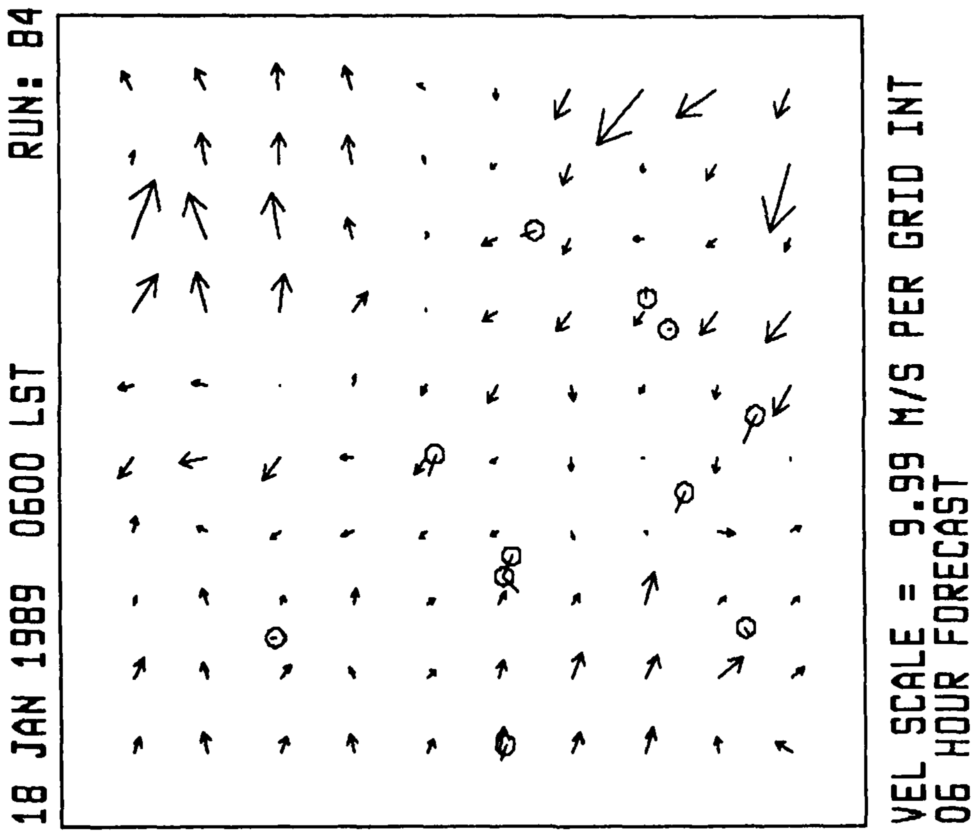

01 SEP 1987 0000 LST
RUN: B2
VEL SCALE = 9.35 M/S PER GRID INT
24 HOUR FORECAST

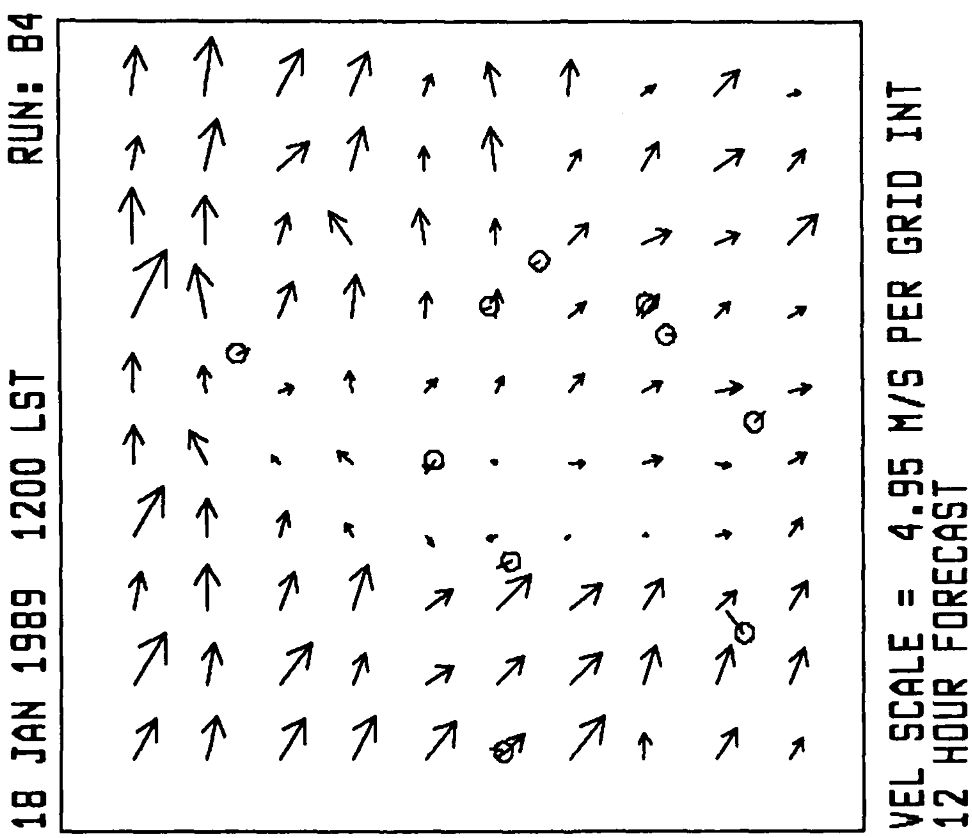

23 FEB 1988 0600 LST RUN: B3
VEL SCALE = 7.99 M/S PER GRID INT
06 HOUR FORECAST

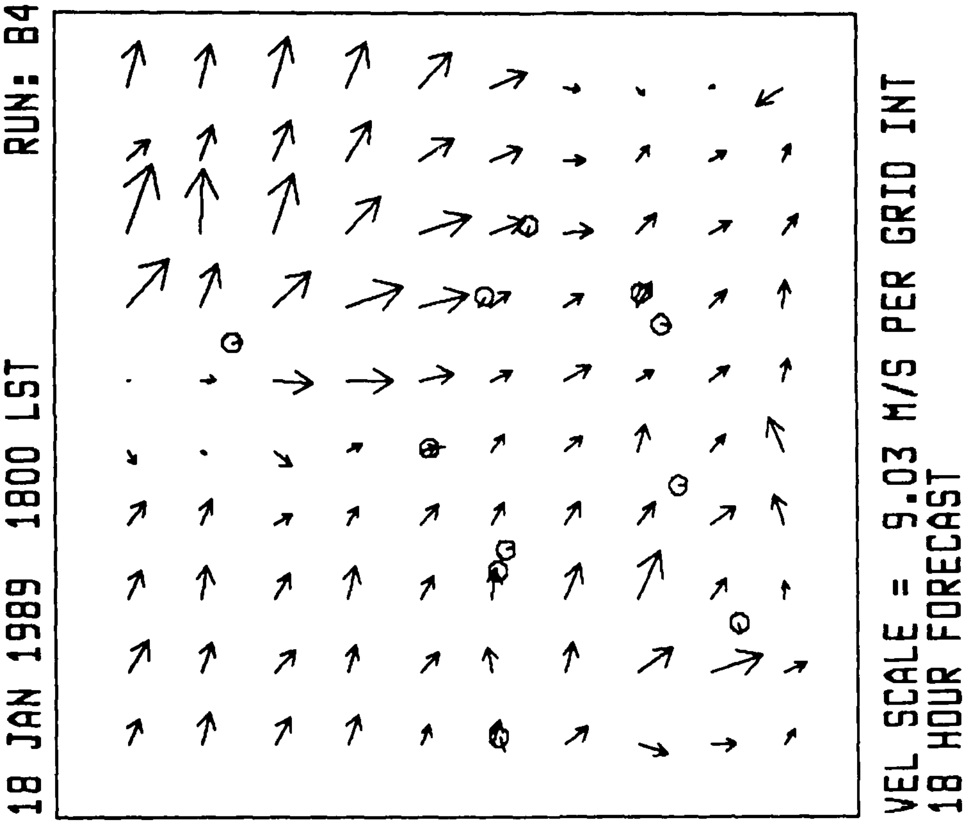

23 FEB 1988 1200 LST RUN: B3
VEL SCALE = 8.68 M/S PER GRID INT
12 HOUR FORECAST


23 FEB 1988 1800 LST RUN: B3
VEL SCALE = 7.75 M/S PER GRID INT
18 HOUR FORECAST


24 FEB 1988 0000 LST
RUN: B3
VEL SCALE = 7.72 M/S PER GRID INT
24 HOUR FORECAST


18 JAN 1989 0600 LST RUN: 84
VEL SCALE = 9.99 M/S PER GRID INT
06 HOUR FORECAST


18 JAN 1989 1200 LST
RUN: B4
VEL SCALE = 4.95 M/S PER GRID INT
12 HOUR FORECAST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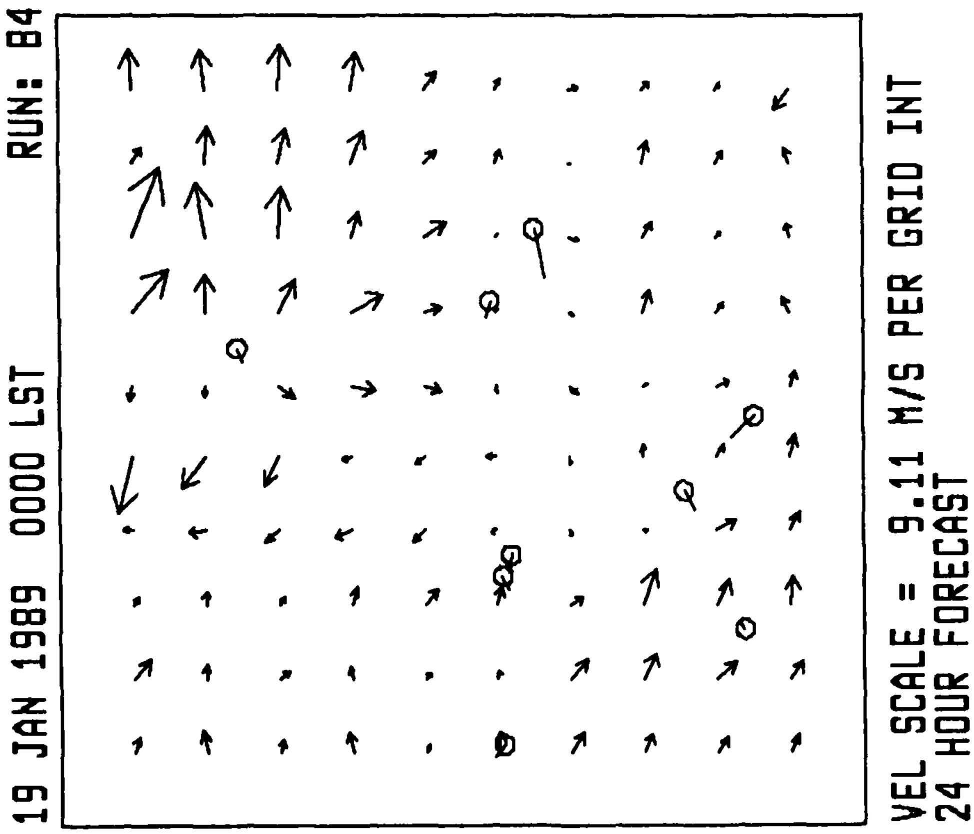
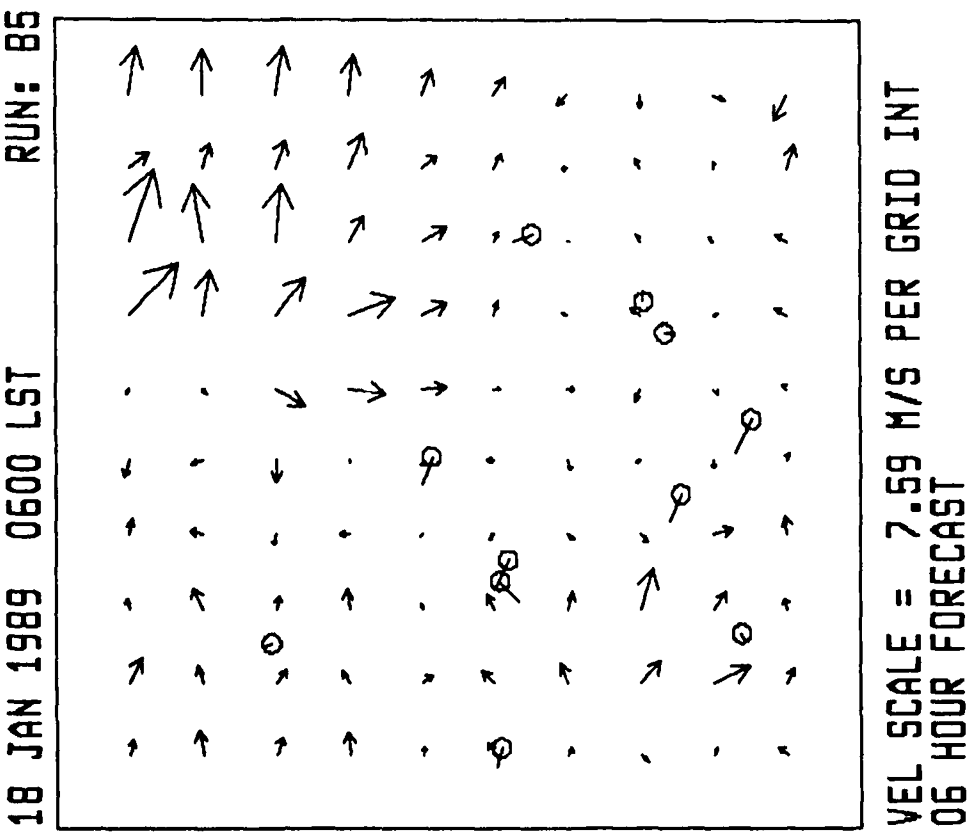
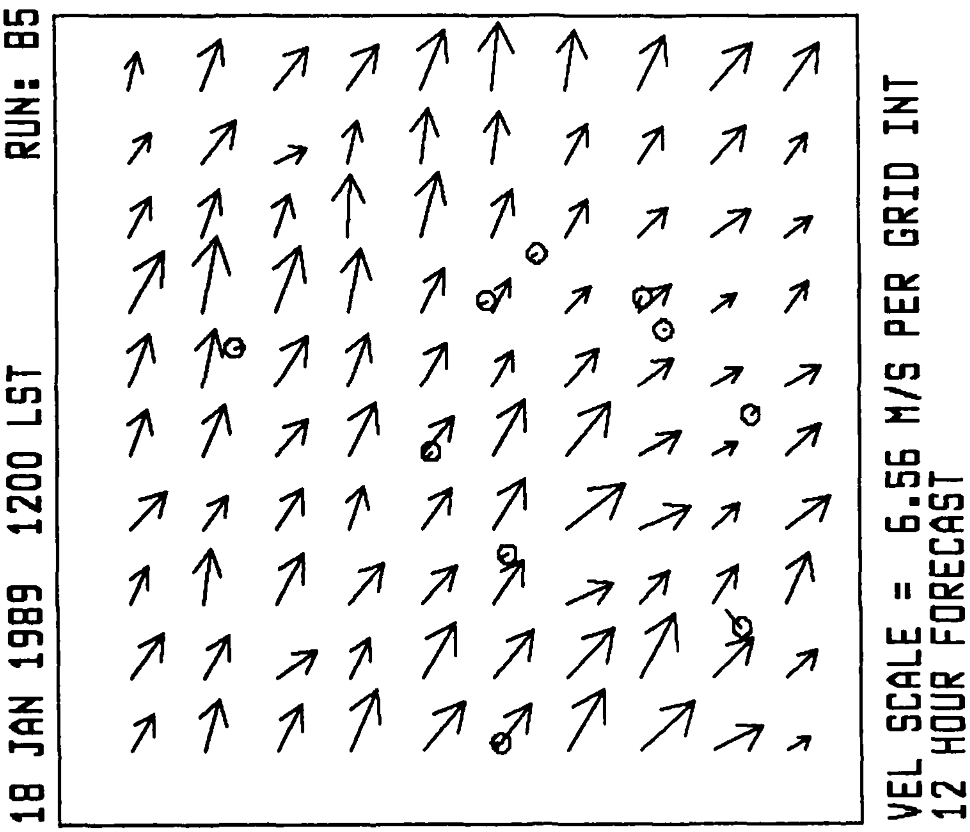
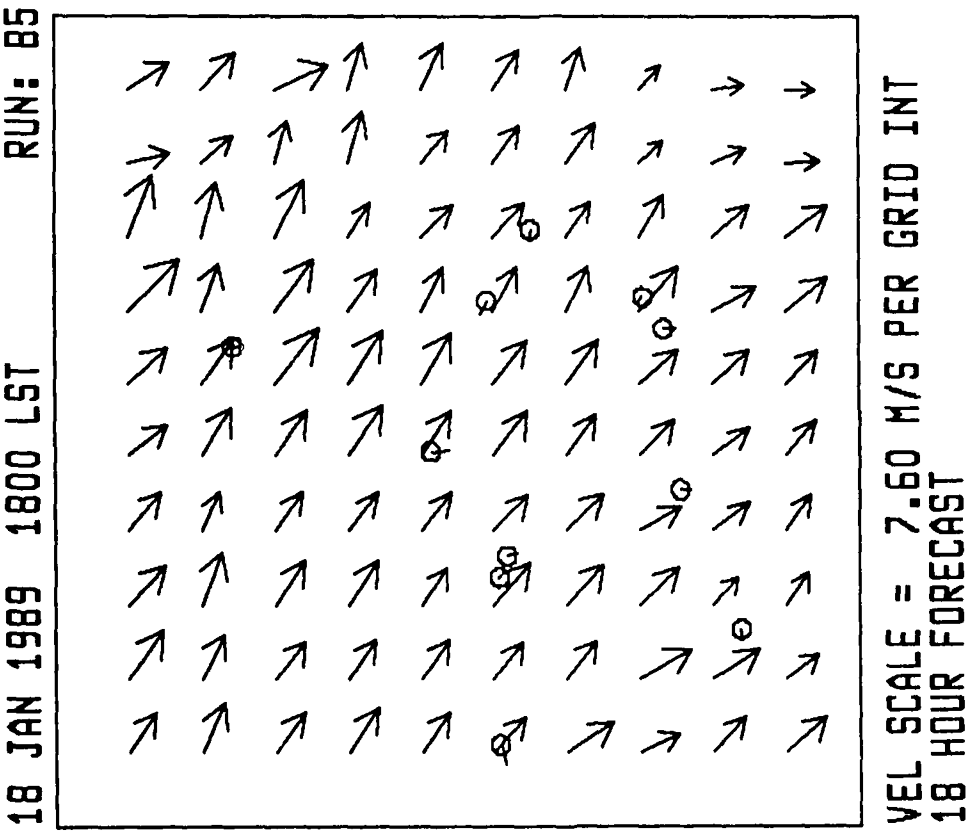
RUN: B4
VEL SCALE = 9.03 M/S PER GRID INT
18 HOUR FORECAST


19 JAN 1989 0000 LST
RUN: B4
VEL SCALE = 9.11 M/S PER GRID INT
24 HOUR FORECAST

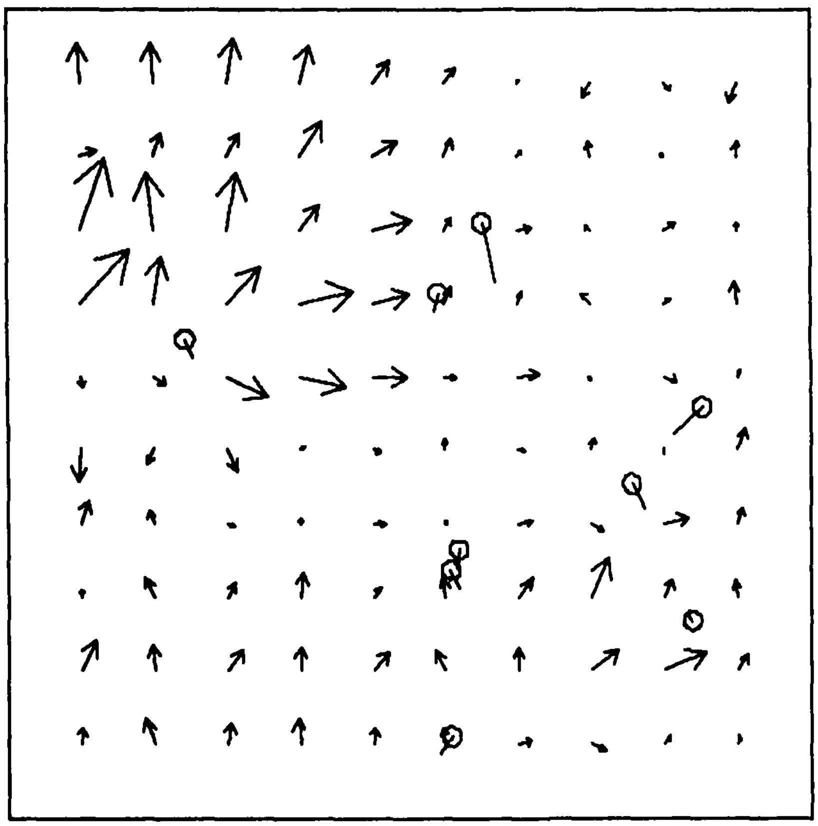

18 JAN 1989 0600 LST RUN: B5
VEL SCALE = 7.59 M/S PER GRID INT
06 HOUR FORECAST


18 JAN 1989 1200 LST
RUN: B5
VEL SCALE = 6.56 M/S PER GRID INT
12 HOUR FORECAST

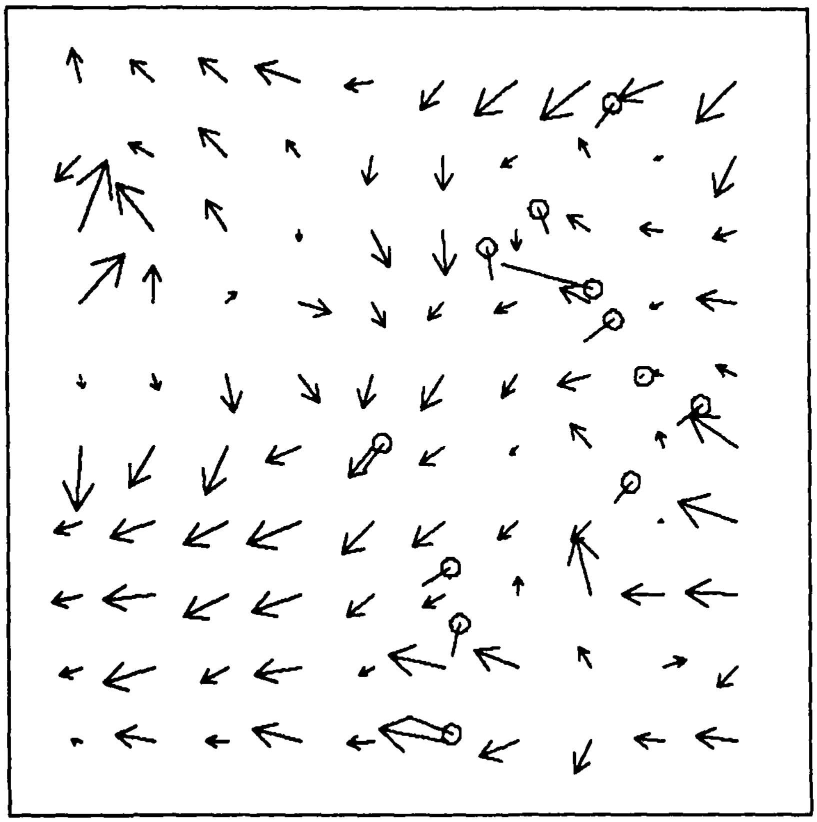


18 JAN 1989 1800 LST RUN: B5
VEL SCALE = 7.60 M/S PER GRID INT
18 HOUR FORECAST

19 JAN 1989 0000 LST RUN: B5

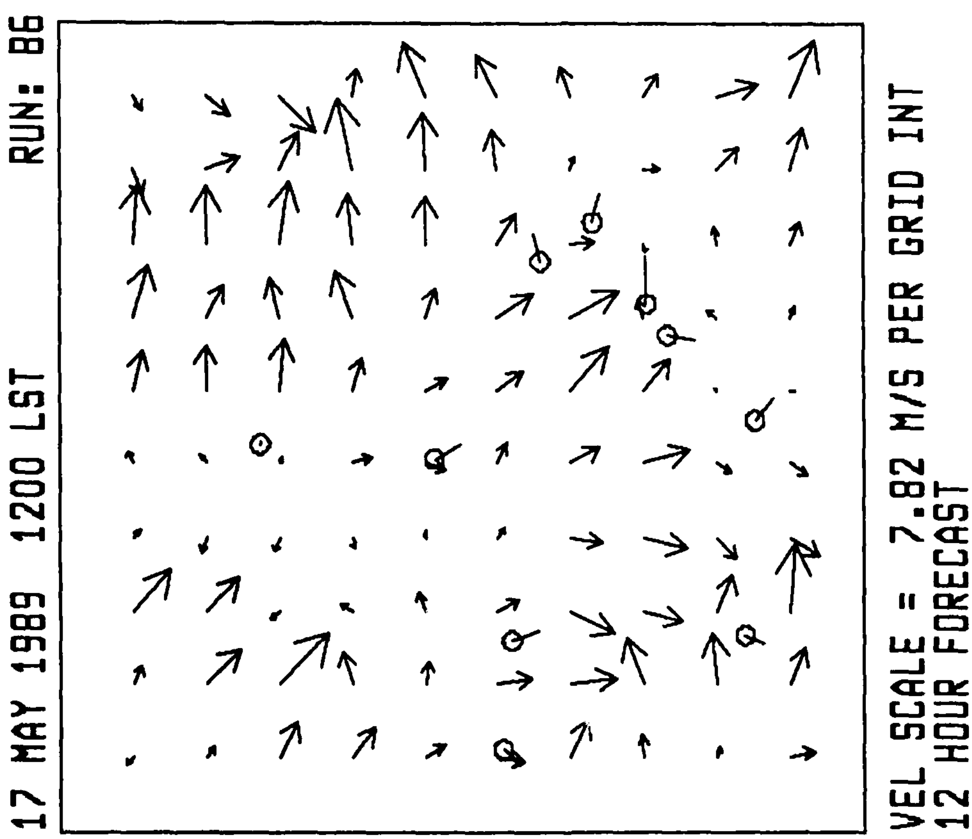


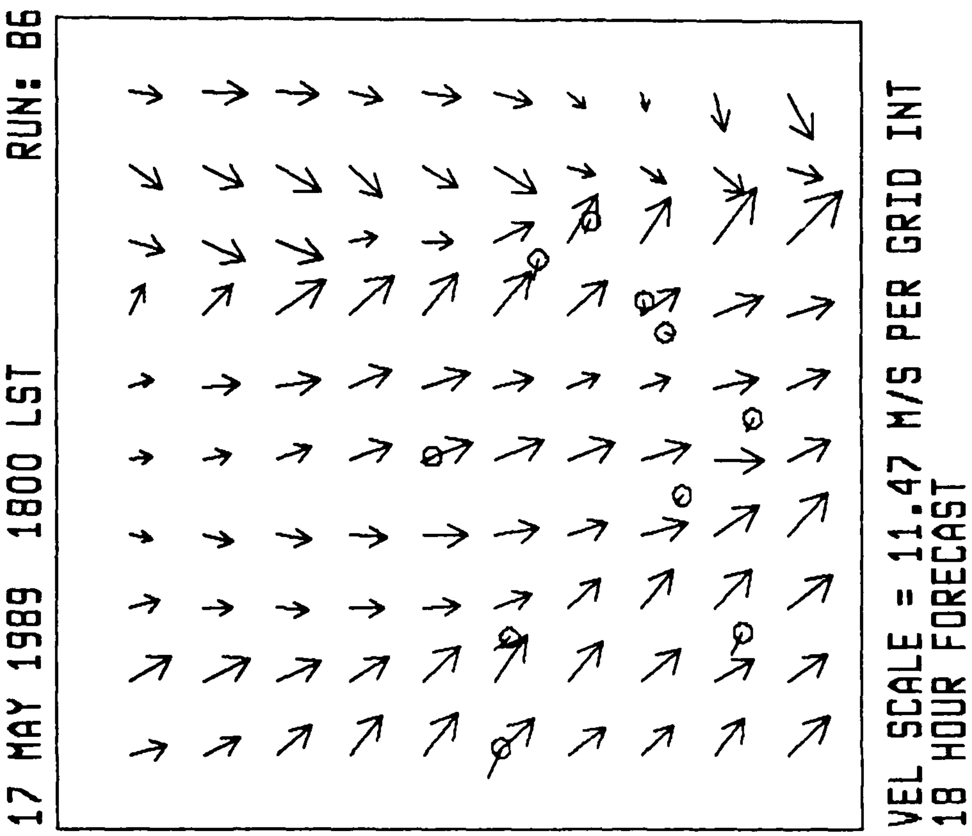
VEL SCALE = 7.29 M/S PER GRID INT
24 HOUR FORECAST



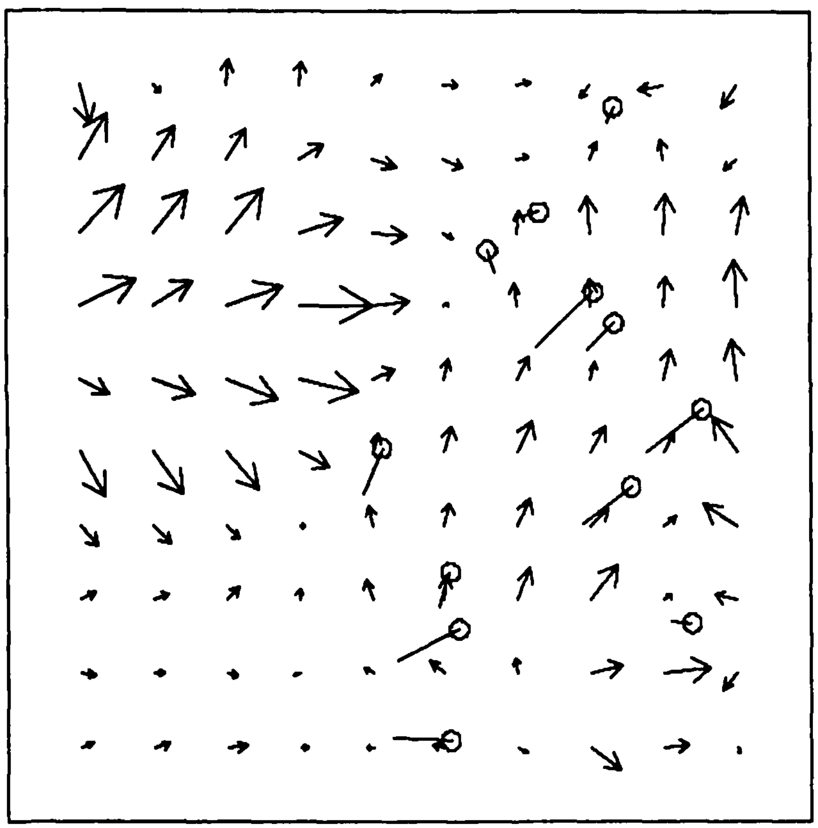
17 MAY 1989 0600 LST RUN: B6

VEL SCALE = 4.68 M/S PER GRID INT
06 HOUR FORECAST


17 MAY 1989 1200 LST
RUN: B6
VEL SCALE = 7.82 M/S PER GRID INT
12 HOUR FORECAST

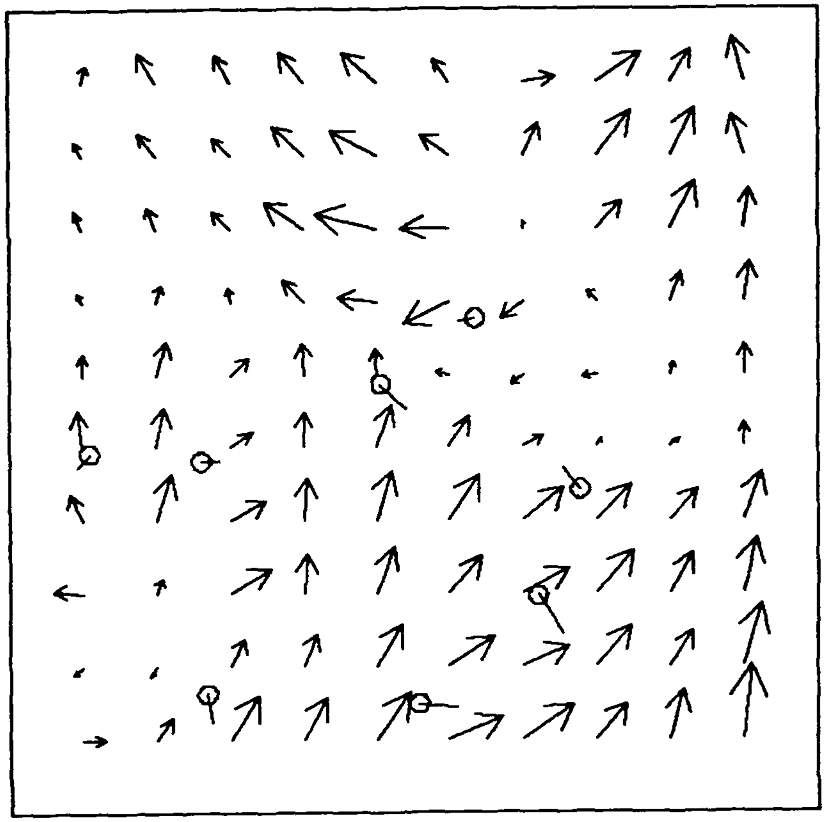

17 MAY 1989 1800 LST
RUN: B6
VEL SCALE = 11.47 M/S PER GRID INT
18 HOUR FORECAST

18 MAY 1989 0000 LST RUN: 86



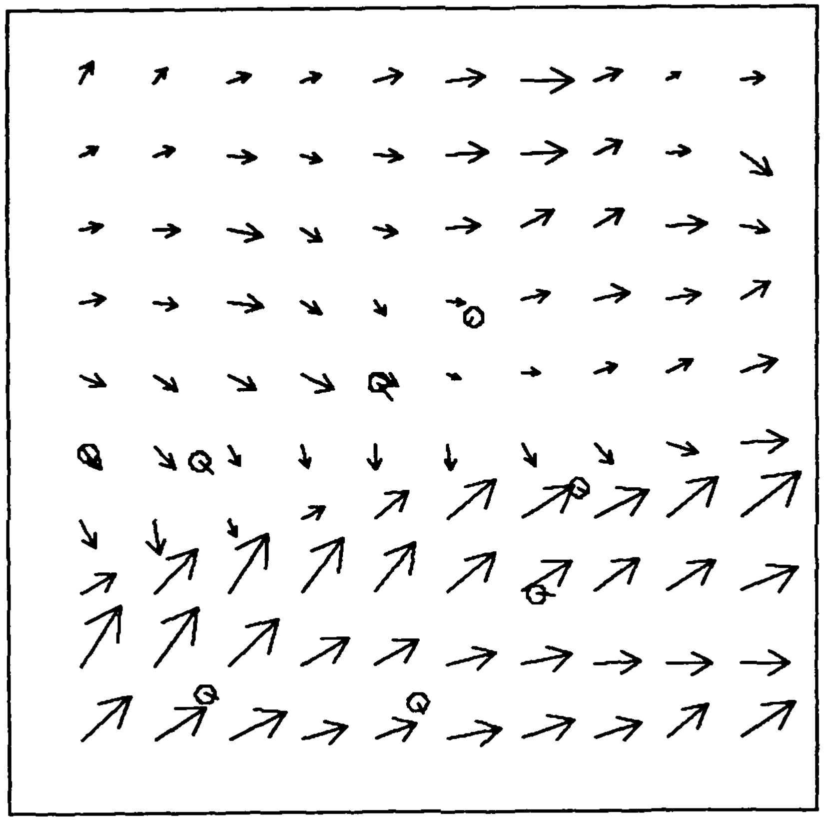
VEL SCALE = 7.44 M/S PER GRID INT
24 HOUR FORECAST

19 MAY 1989 0600 LST RUN: B7

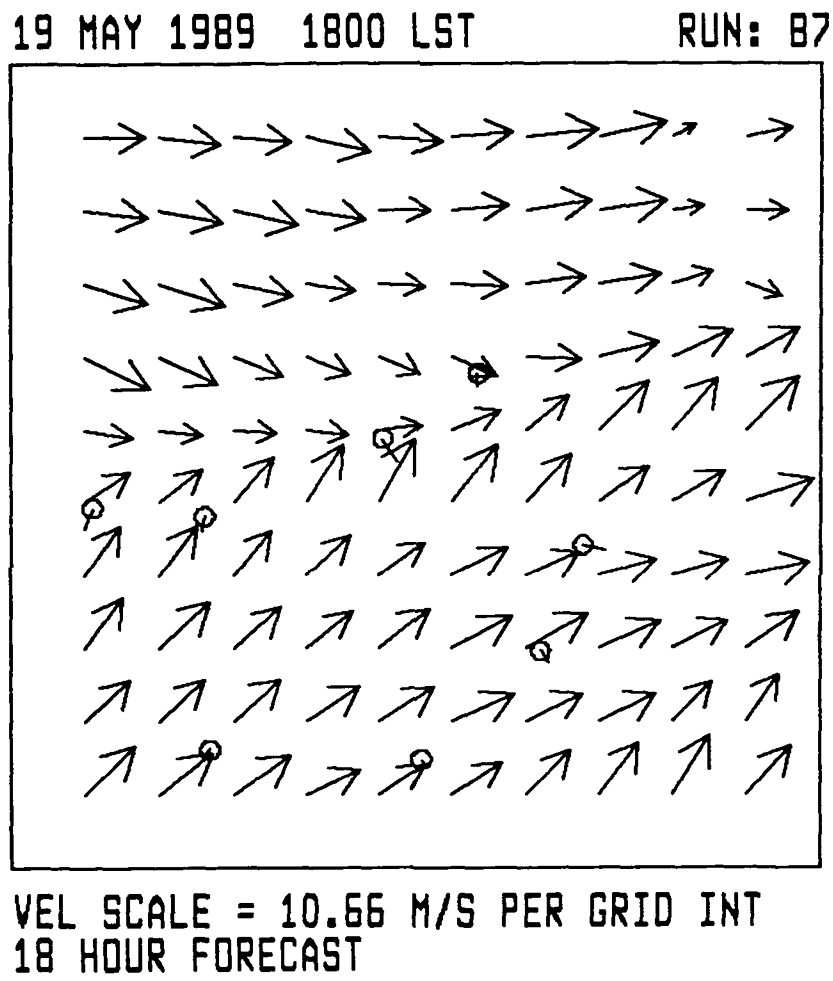


VEL SCALE = 7.91 M/S PER GRID INT
06 HOUR FORECAST

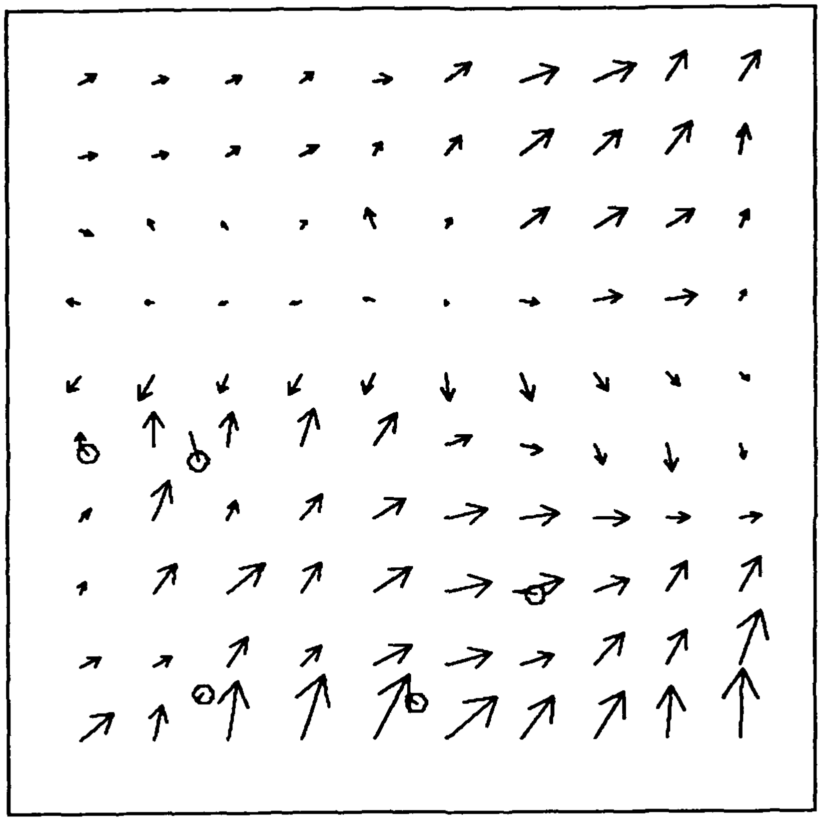
19 MAY 1989 1200 LST RUN: B7



VEL SCALE = 12.83 M/S PER GRID INT
12 HOUR FORECAST

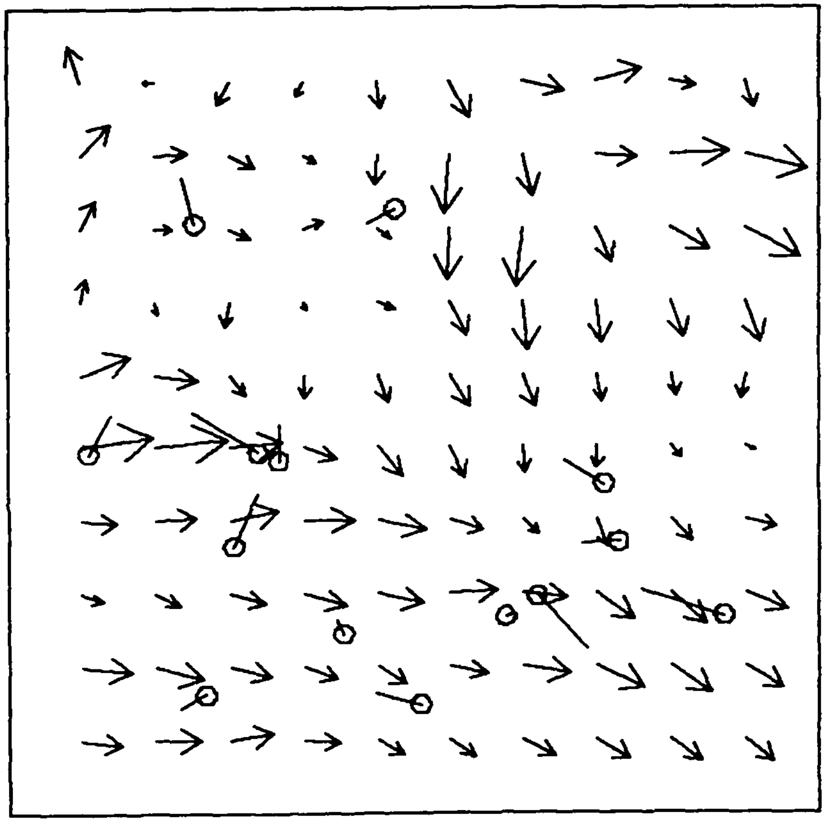

19 MAY 1989 1800 LST
RUN: B7
VEL SCALE = 10.66 M/S PER GRID INT
18 HOUR FORECAST

20 MAY 1989 0000 LST RUN: B7

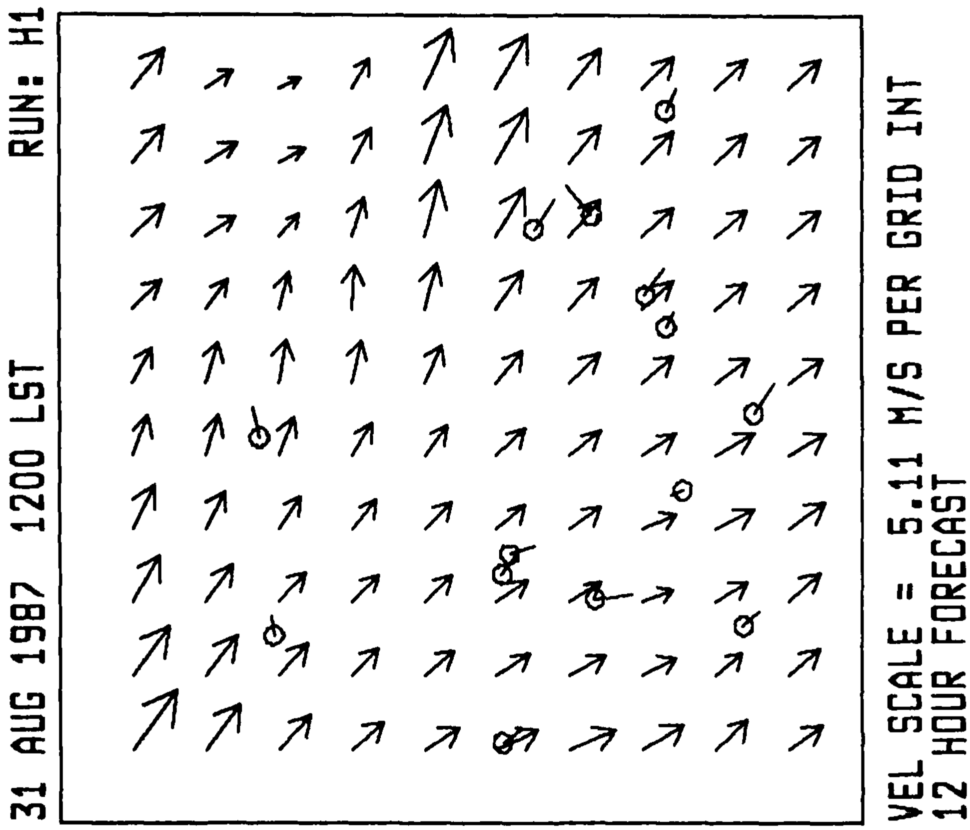


VEL SCALE = 9.12 M/S PER GRID INT
24 HOUR FORECAST

31 AUG 1987 0600 LST RUN: H1



VEL SCALE = 3.57 M/S PER GRID INT
06 HOUR FORECAST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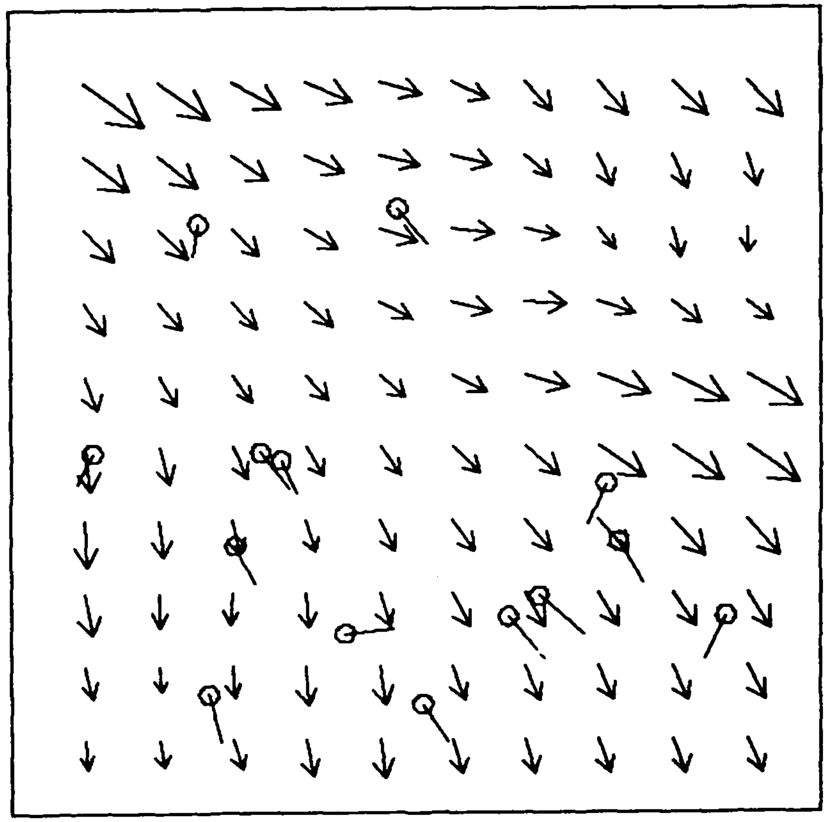
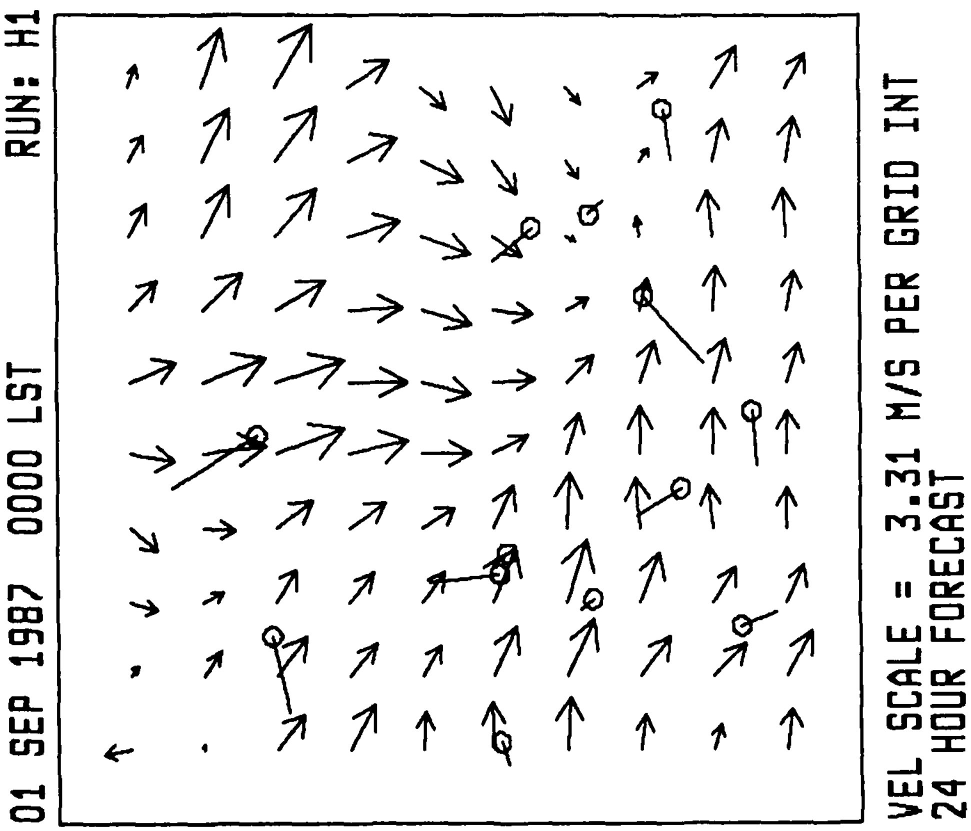
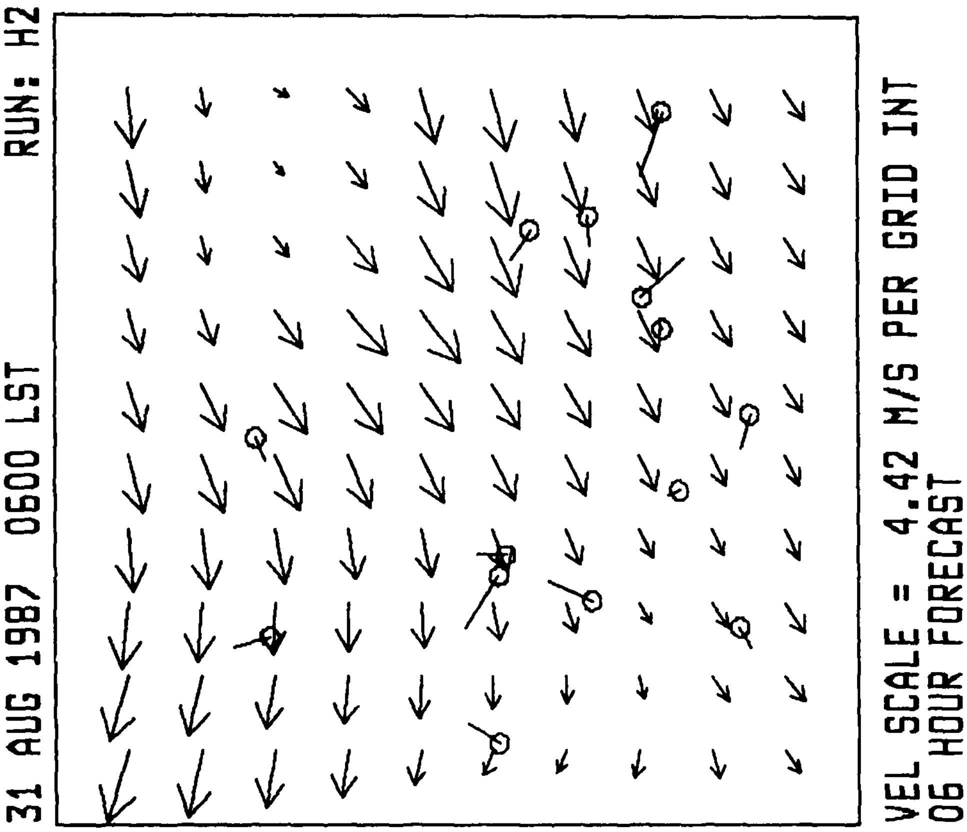
VEL SCALE = 5.11 M/S PER GRID INT
12 HOUR FORECAST

31 AUG 1987 1800 LST RUN: H1



VEL SCALE = 6.68 M/S PER GRID INT
18 HOUR FORECAST


01 SEP 1987 0000 LST
RUN: H1
VEL SCALE = 3.31 M/S PER GRID INT
24 HOUR FORECAST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RUN: H2
VEL SCALE = 4.42 M/S PER GRID INT
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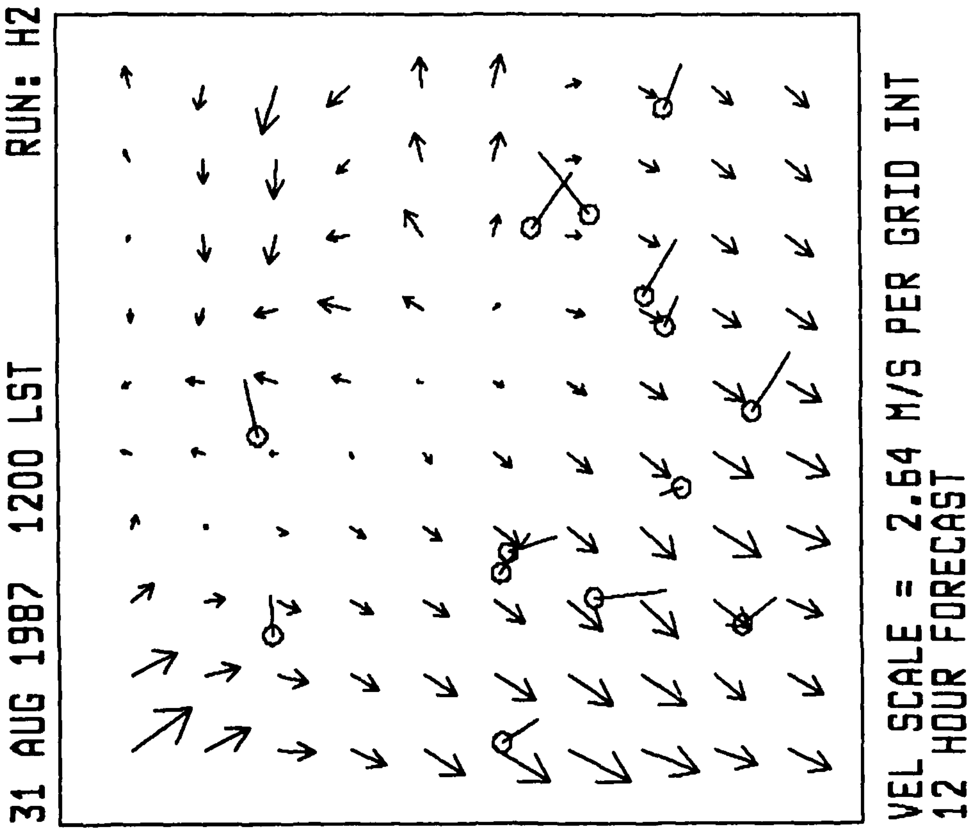
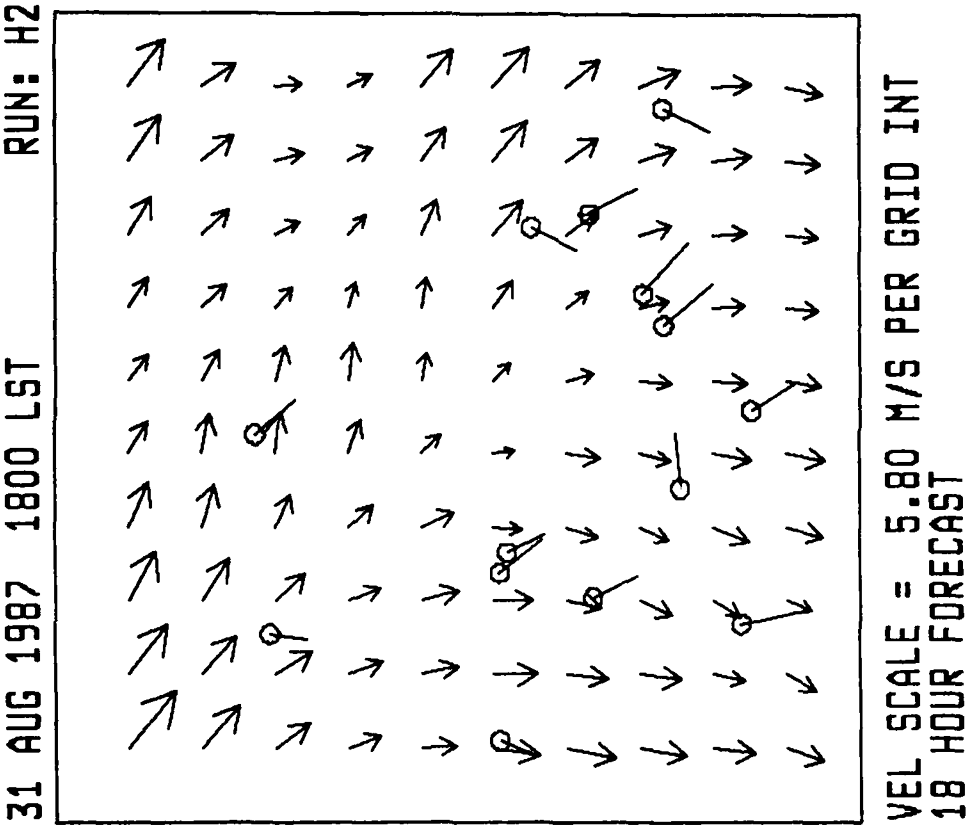
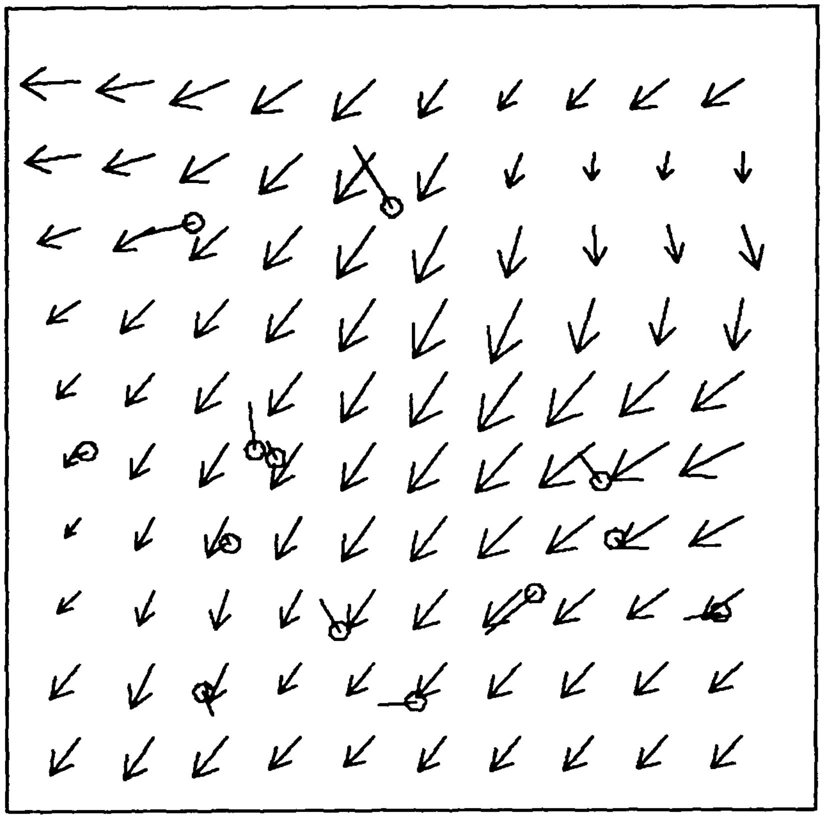
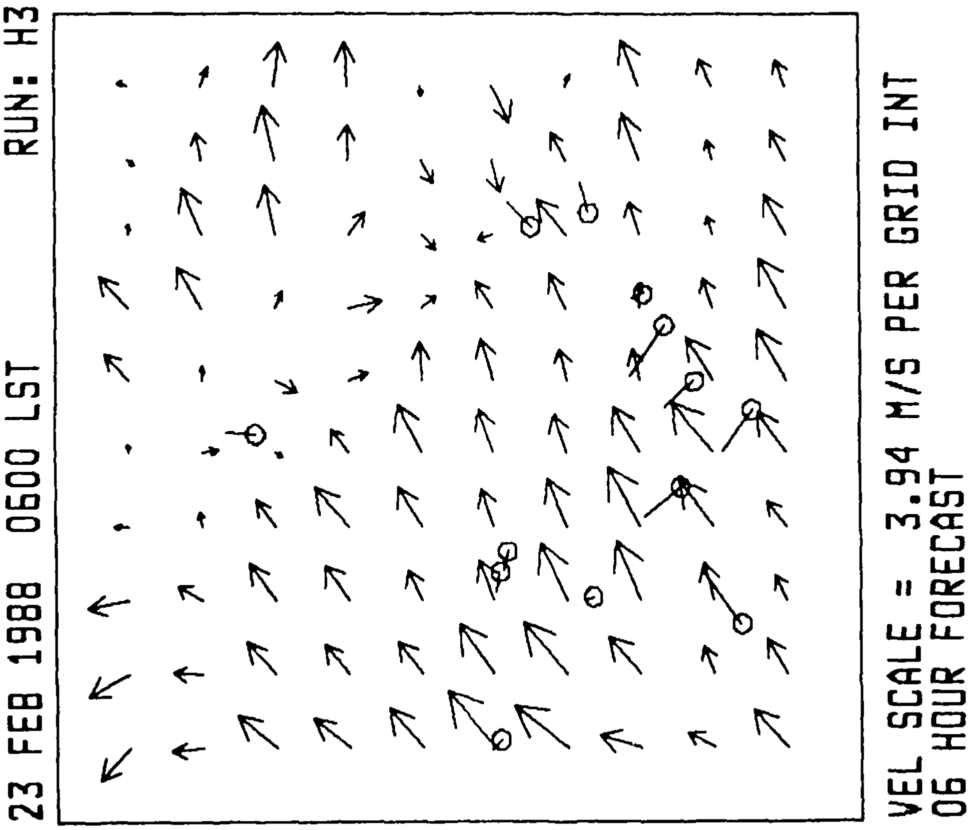

31 AUG 1987 1200 LST
RUN: H2
VEL SCALE = 2.64 M/S PER GRID INT
12 HOUR FORECAST


31 AUG 1987 1800 LST
RUN: H2
VEL SCALE = 5.80 M/S PER GRID INT
18 HOUR FORECAST

01 SEP 1987 0000 LST RUN: H2



VEL SCALE = 4.74 M/S PER GRID INT
24 HOUR FORECAST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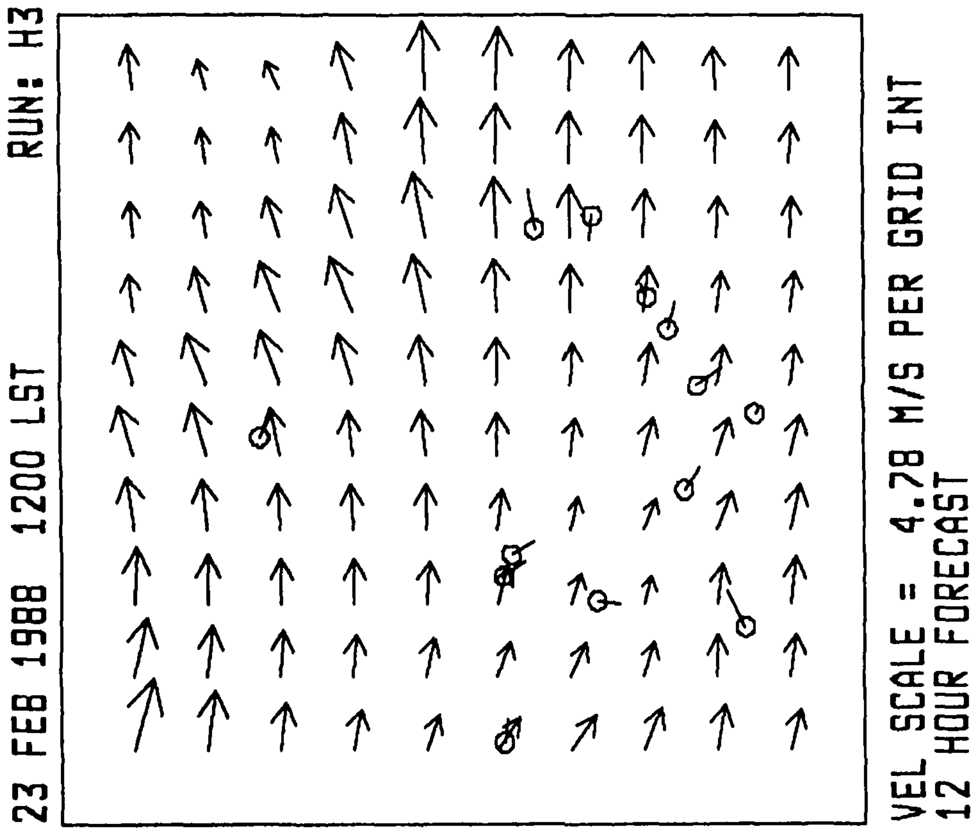
RUN: H3
VEL SCALE = 3.94 M/S PER GRID INT
06 HOUR FORECAST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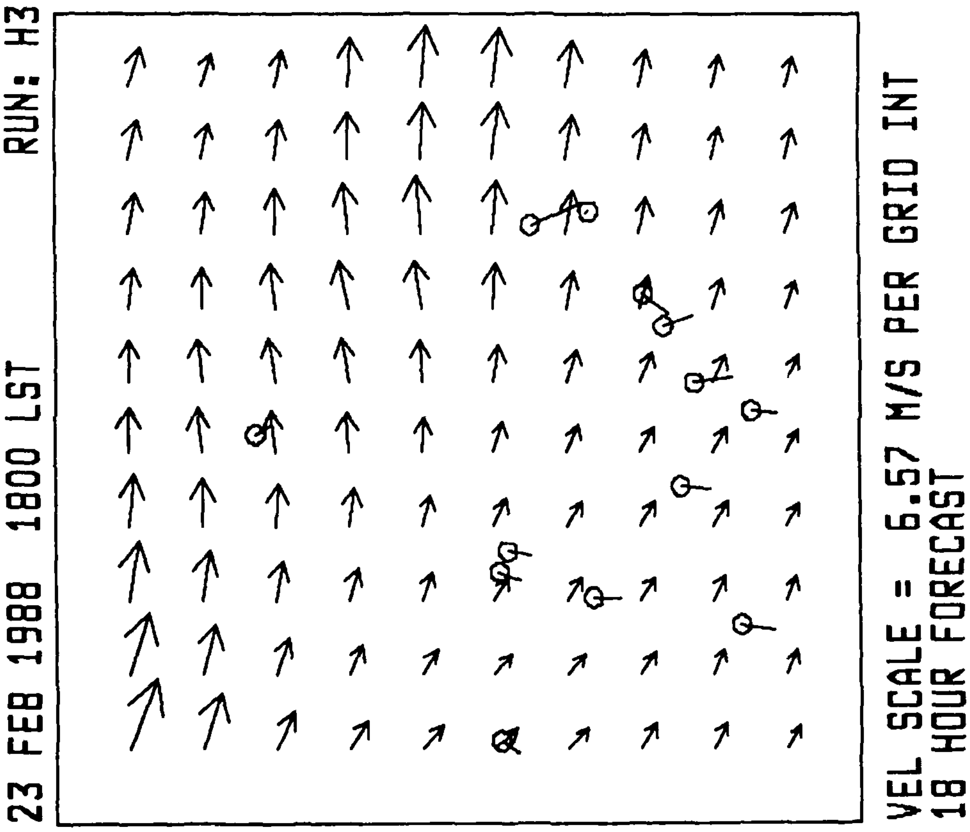
RUN: H3
VEL SCALE = 4.78 M/S PER GRID INT
12 HOUR FORECAST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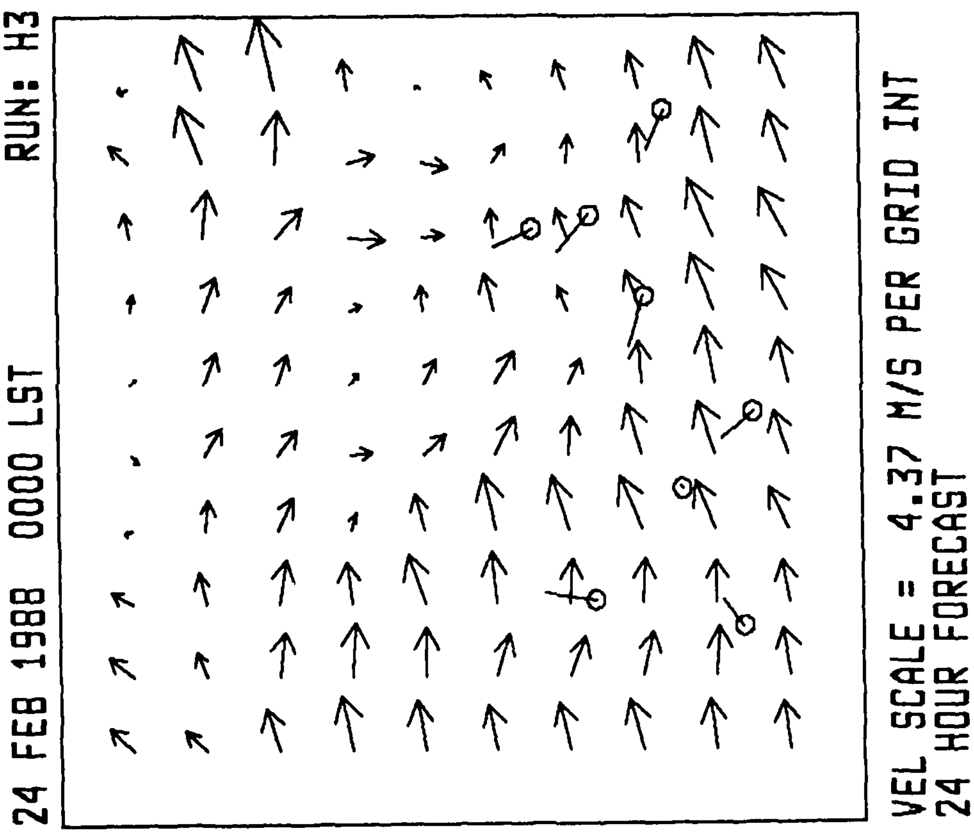
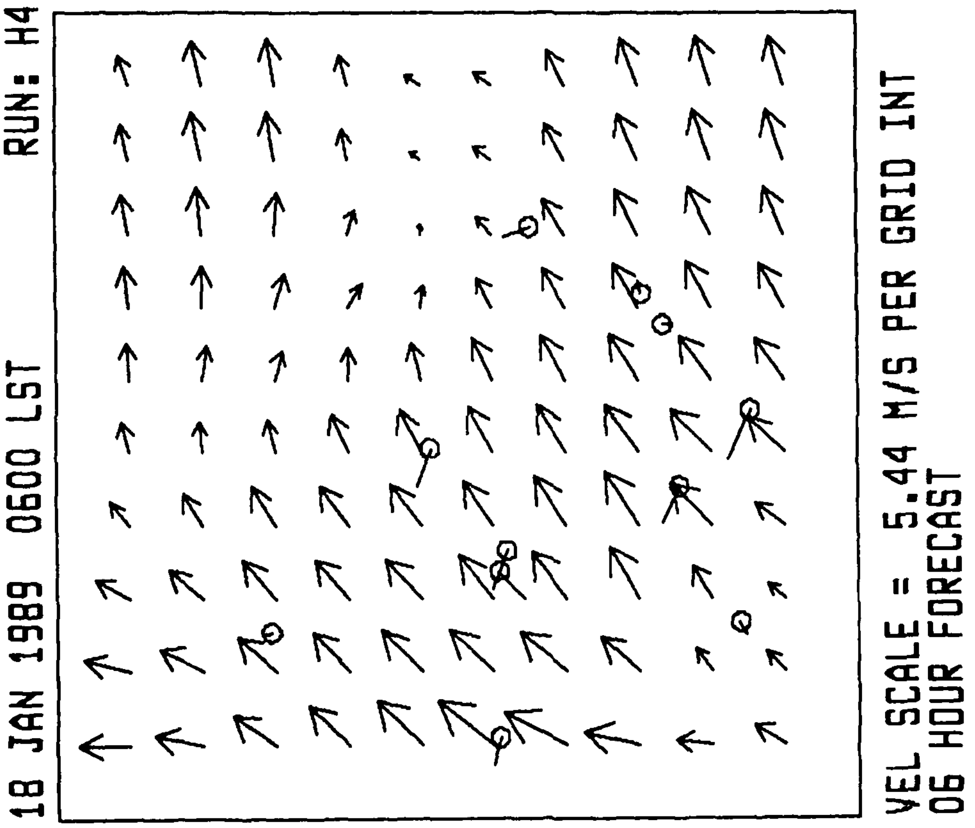
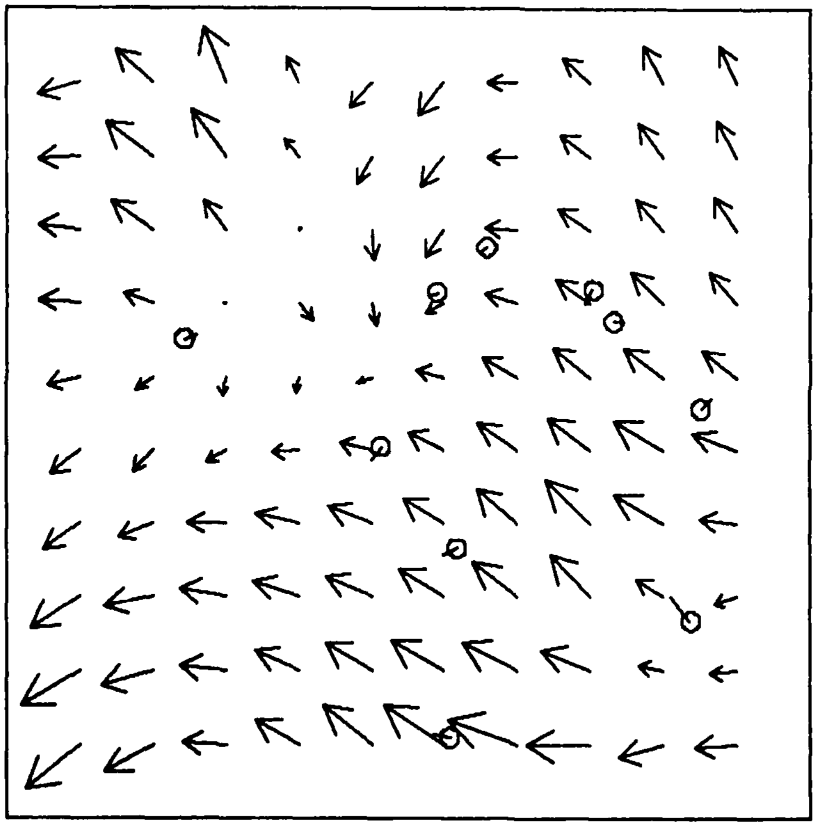
VEL SCALE = 6.57 M/S PER GRID INT
18 HOUR FORECAST

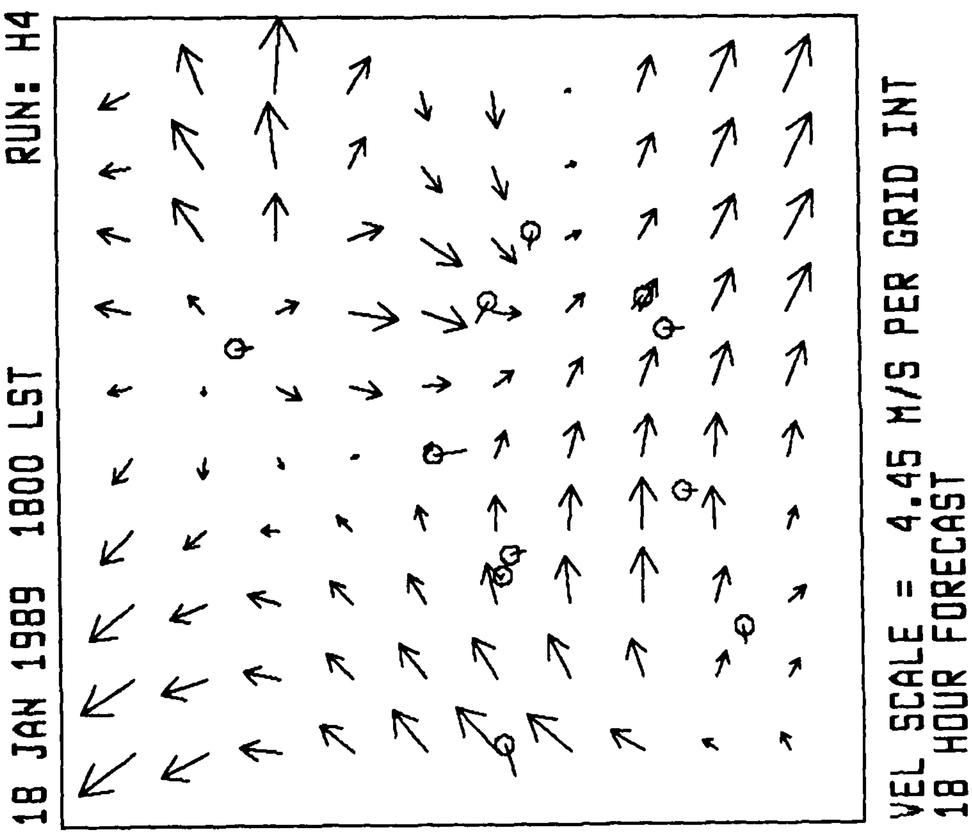

24 FEB 1988 0000 LST
RUN: H3
VEL SCALE = 4.37 M/S PER GRID INT
24 HOUR FORECAST

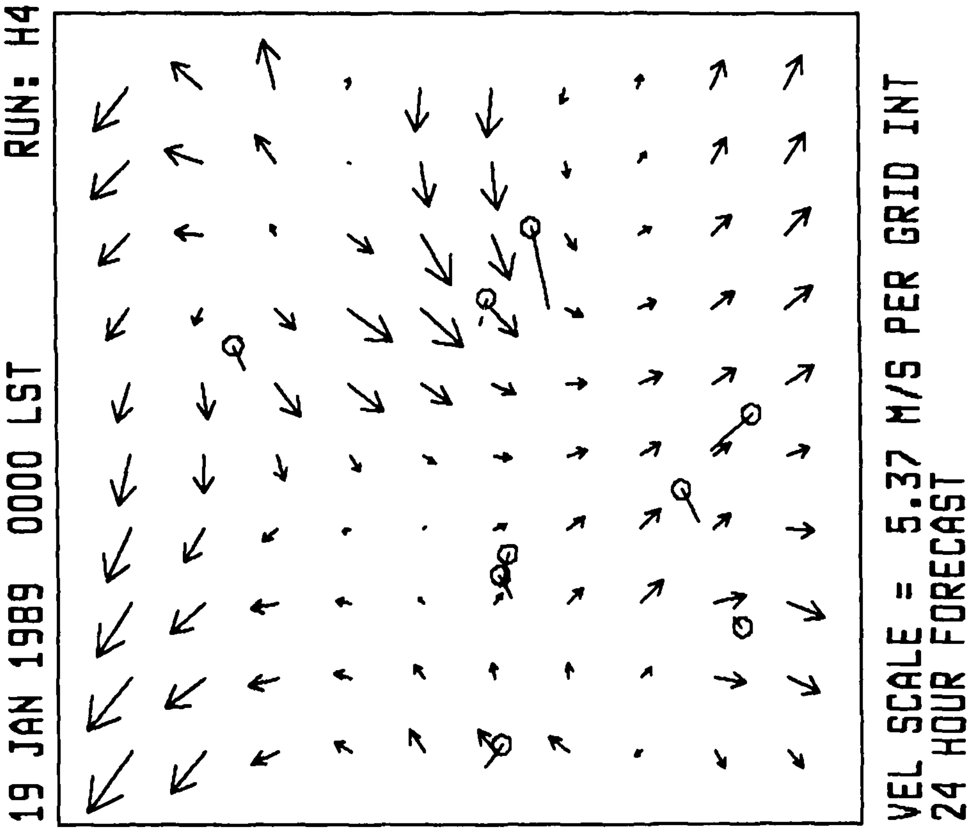

18 JAN 1989 0600 LST
RUN: H4
VEL SCALE = 5.44 M/S PER GRID INT
06 HOUR FORECAST

18 JAN 1989 1200 LST RUN: H4

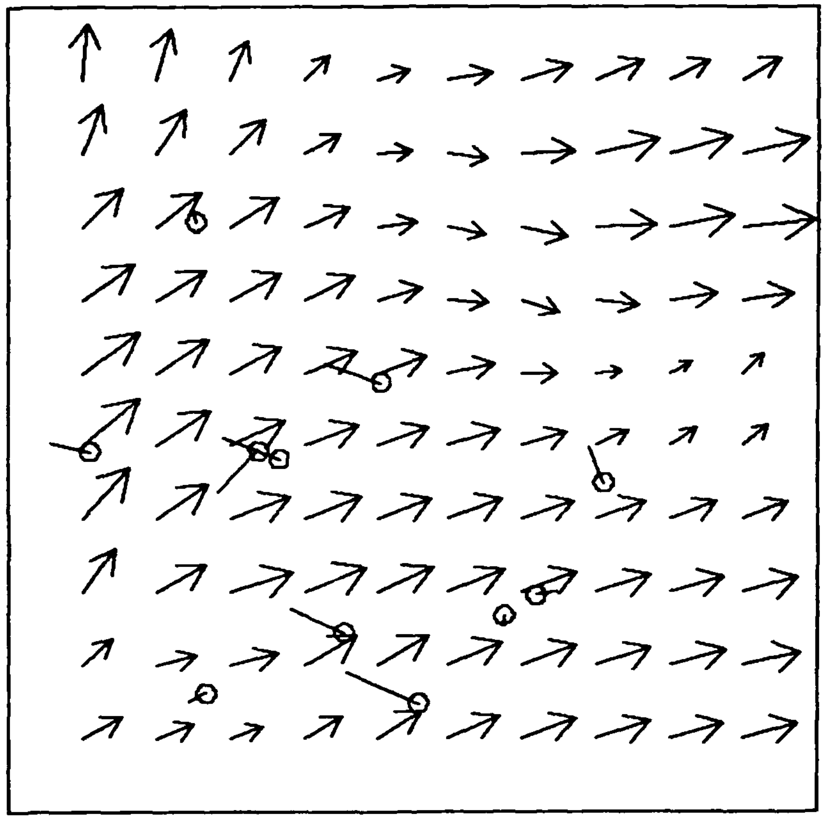


VEL SCALE = 4.78 M/S PER GRID INT
12 HOUR FORECAST

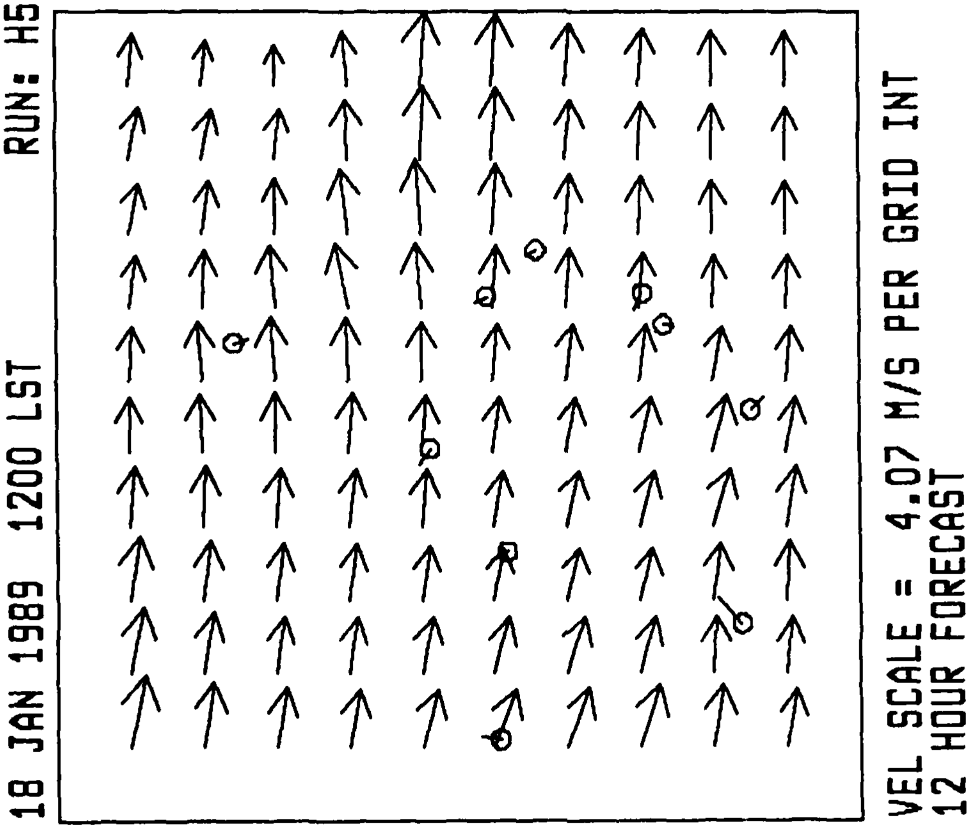

18 JAN 1989 1800 LST RUN: H4
VEL SCALE = 4.45 M/S PER GRID INT
18 HOUR FORECAST

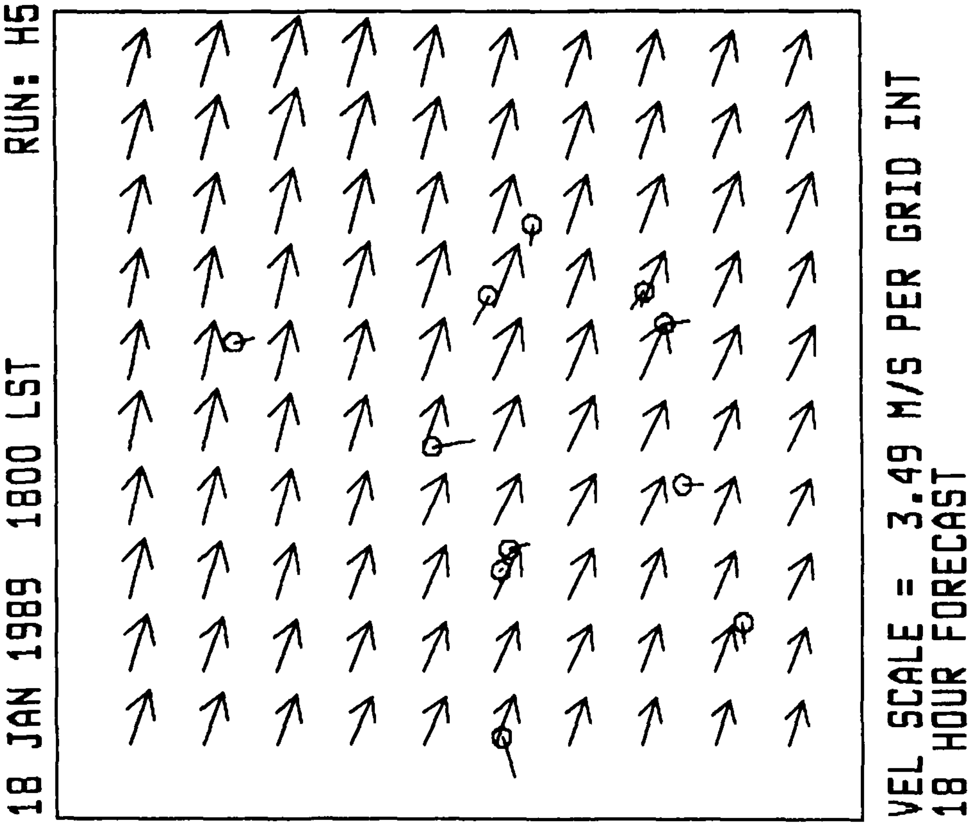

19 JAN 1989 0000 LST
RUN: H4
VEL SCALE = 5.37 M/S PER GRID INT
24 HOUR FORECAST

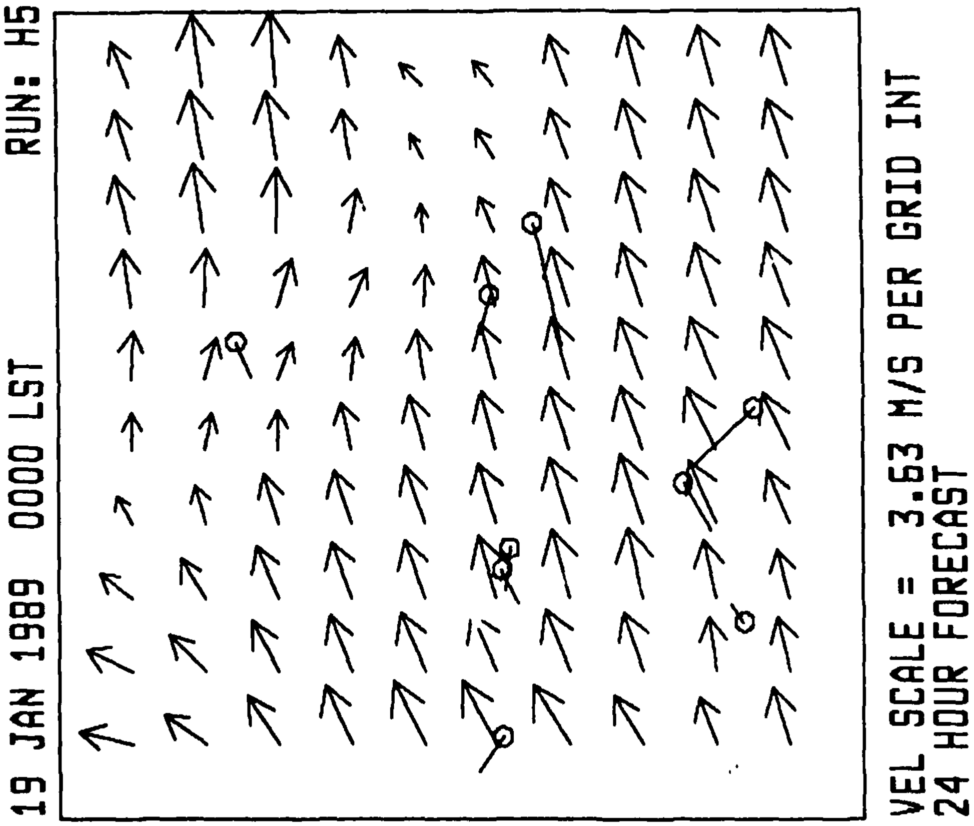
18 JAN 1989 0600 LST RUN: H5

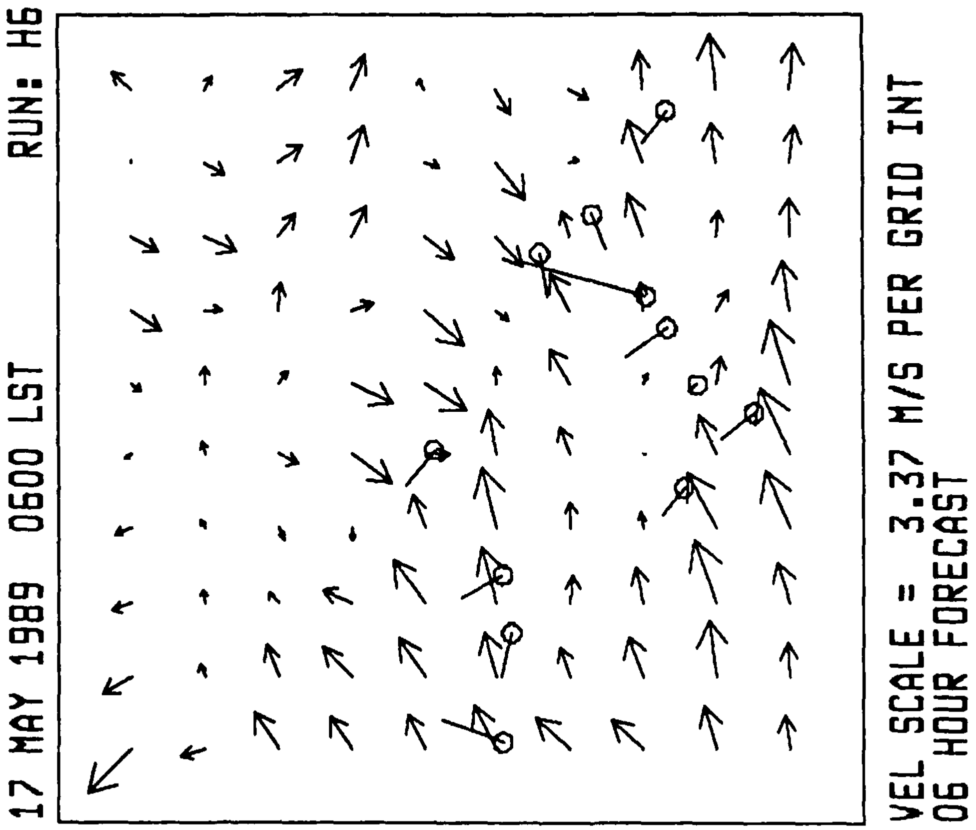


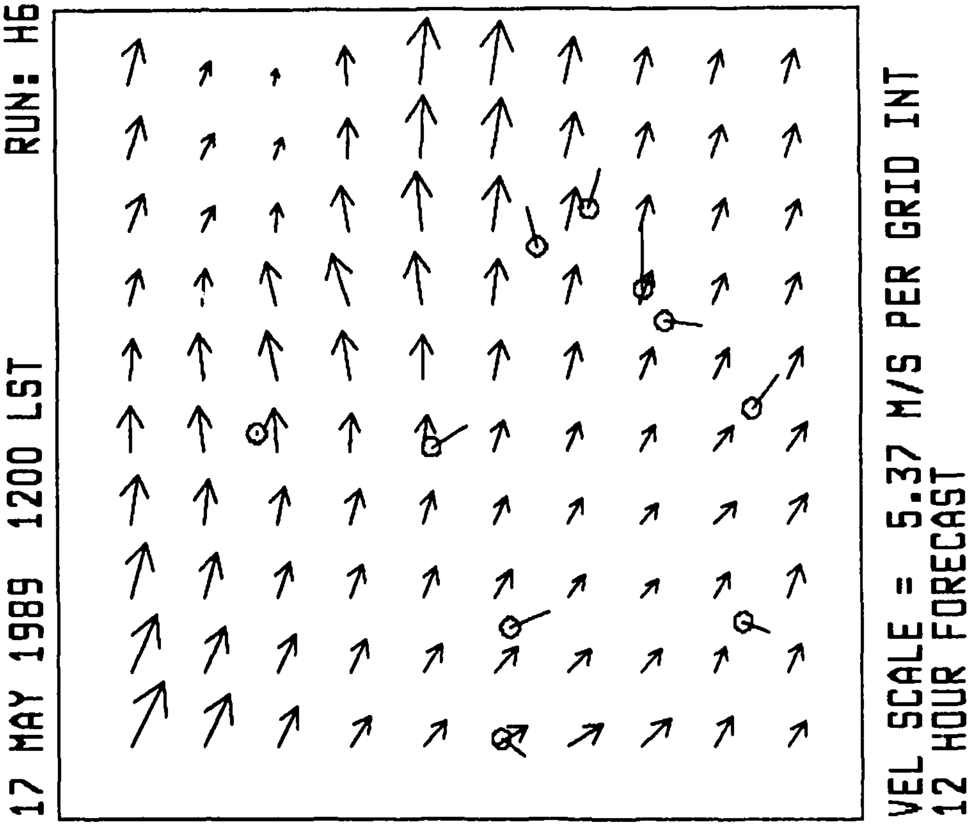
VEL SCALE = 3.68 M/S PER GRID INT
06 HOUR FORECAST

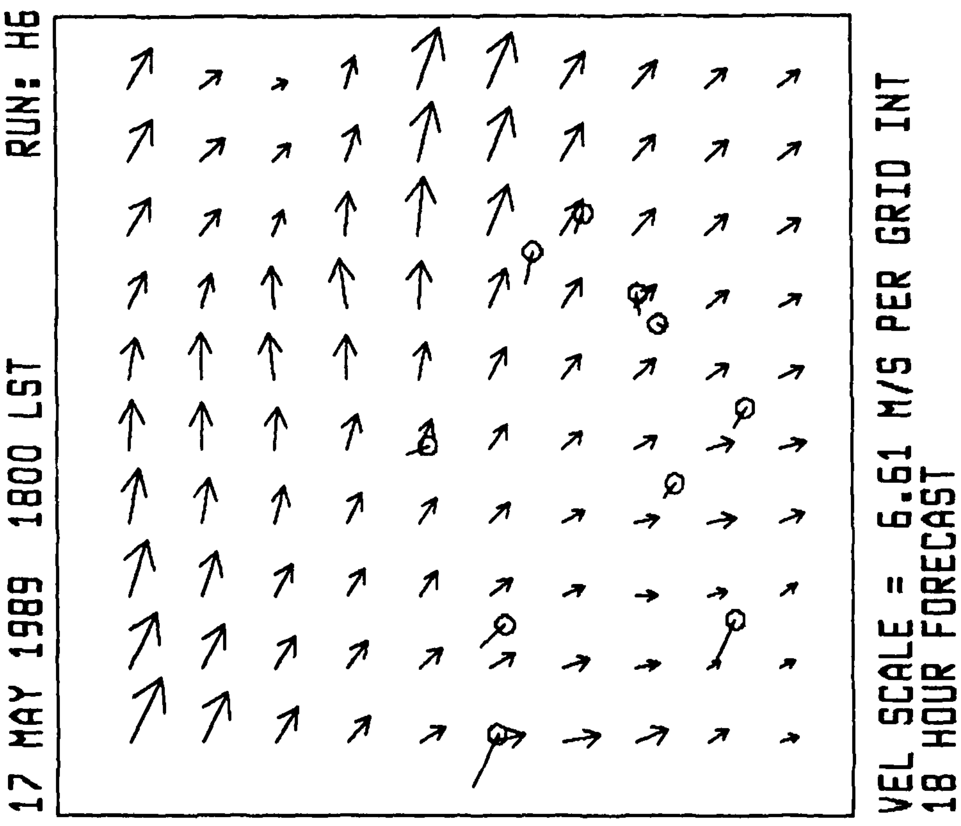

18 JAN 1989 1200 LST RUN: H5
VEL SCALE = 4.07 M/S PER GRID INT
12 HOUR FORECAST

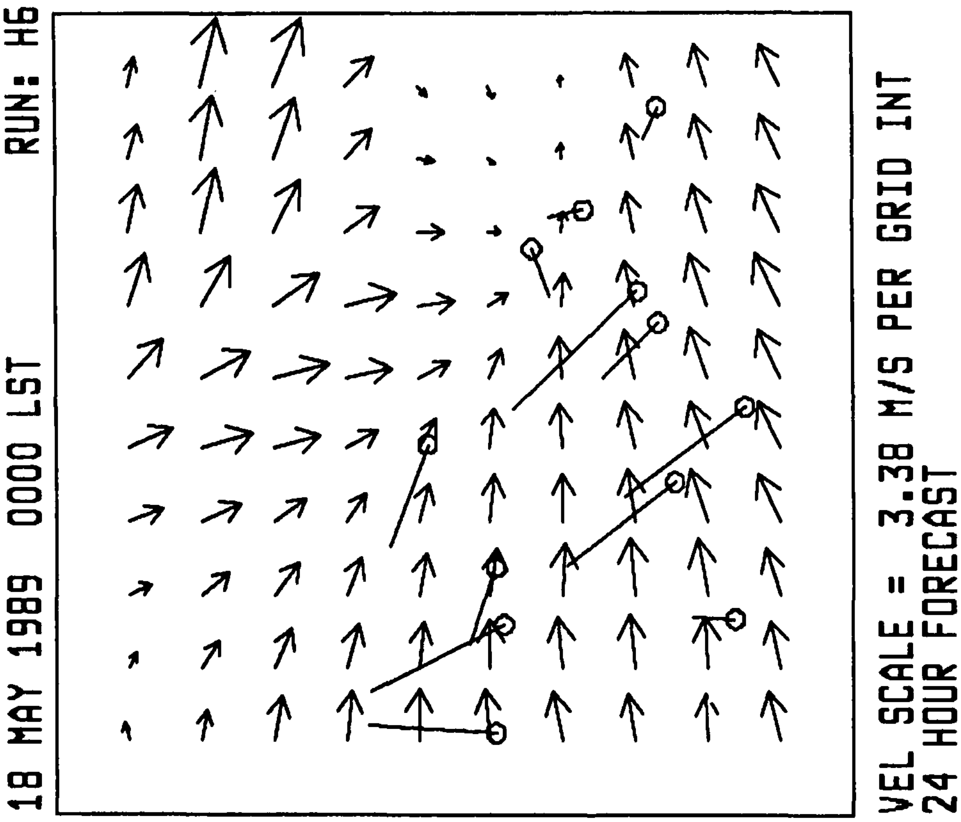

18 JAN 1989 1800 LST
RUN: H5
VEL SCALE = 3.49 M/S PER GRID INT
18 HOUR FORECAST

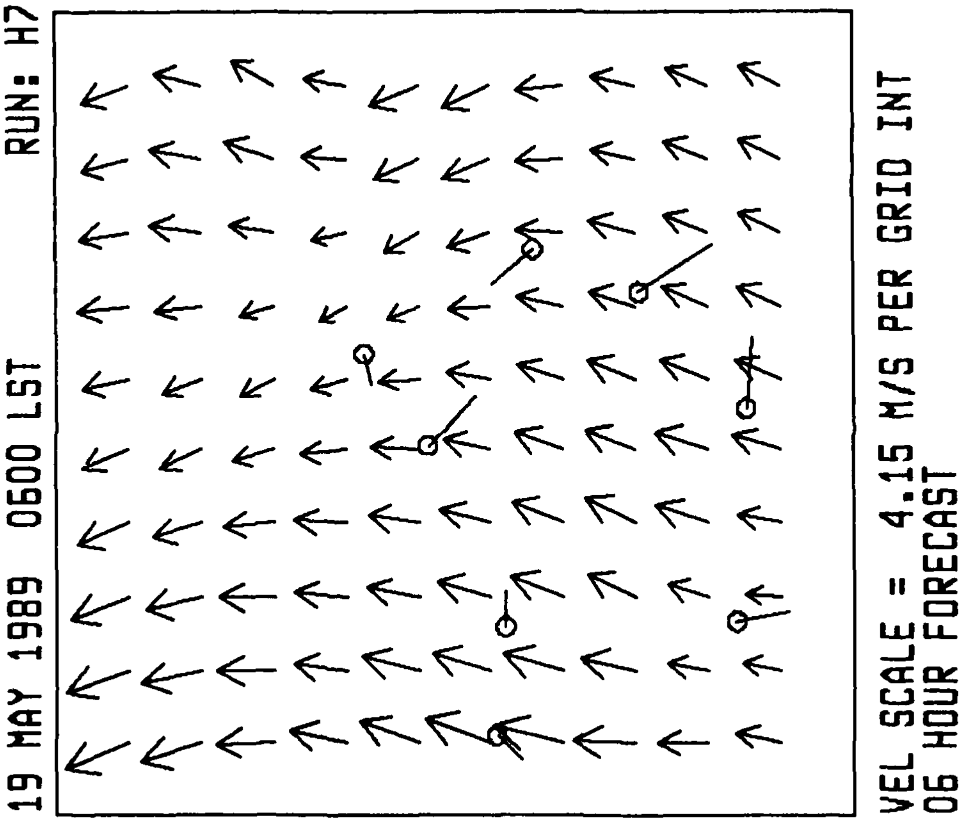

19 JAN 1989 0000 LST
RUN: H5
VEL SCALE = 3.63 M/S PER GRID INT
24 HOUR FORECAST


17 MAY 1989 0600 LST RUN: H6
VEL SCALE = 3.37 M/S PER GRID INT
06 HOUR FORECAST

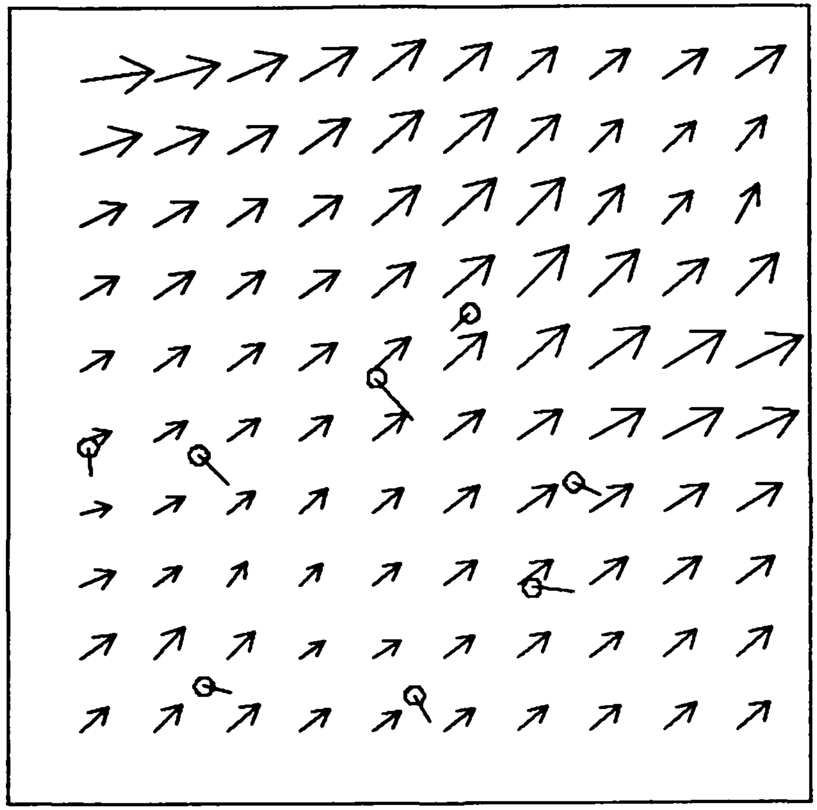

17 MAY 1989 1200 LST RUN: H6
VEL SCALE = 5.37 M/S PER GRID INT
12 HOUR FORECAST


17 MAY 1989 1800 LST RUN: H6
VEL SCALE = 6.61 M/S PER GRID INT
18 HOUR FORECAST

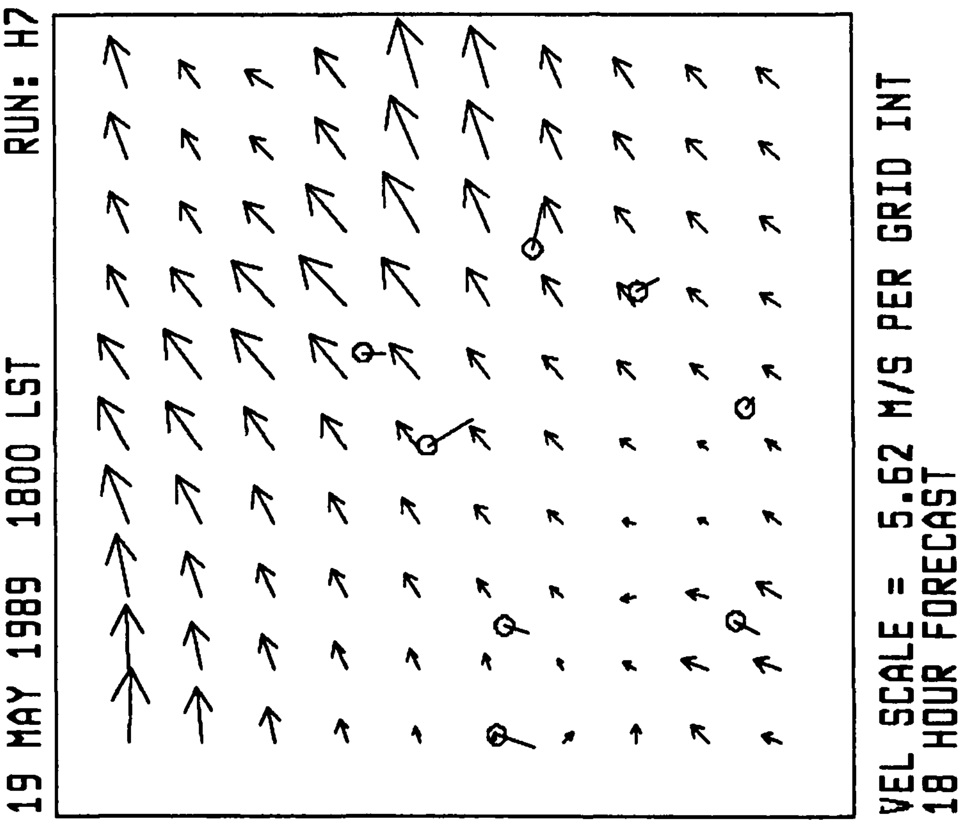

18 MAY 1989 0000 LST
RUN: H6
VEL SCALE = 3.38 M/S PER GRID INT
24 HOUR FORECAST

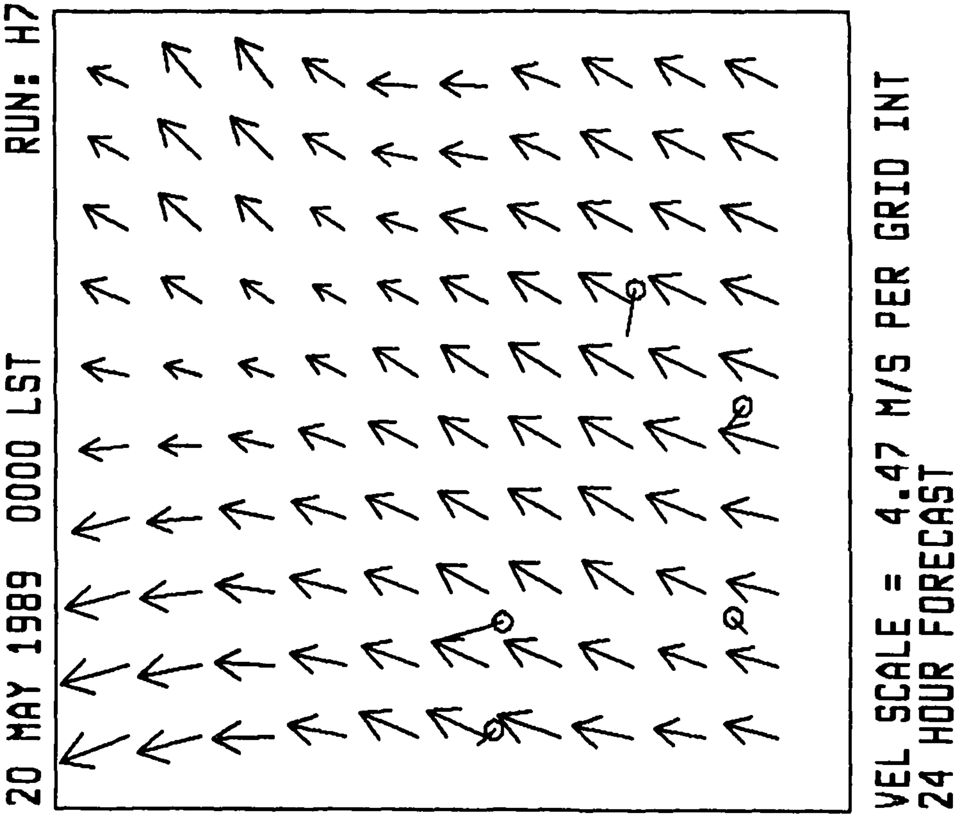

19 MAY 1989 0600 LST
RUN: H7
VEL SCALE = 4.15 M/S PER GRID INT
06 HOUR FORECAST

19 MAY 1989 1200 LST   RUN: H7



VEL SCALE = 5.23 M/S PER GRID INT
12 HOUR FORECAST


19 MAY 1989 1800 LST
RUN: H7
VEL SCALE = 5.62 M/S PER GRID INT
18 HOUR FORECAST


20 MAY 1989 0000 LST
RUN: H7
VEL SCALE = 4.47 M/S PER GRID INT
24 HOUR FORECAST

INTENTIONALLY BLANK

APPENDIX C. REFERENCES

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