The Application of High-Resolution Mesoscale Model Fields with the CALPUFF Disperson Modelling System in Prince George B.C.

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ABSTRACT

Regulatory dispersion models normally require meteorological data to function. In many situations the needed data are not available and must be collected (for a period of a year or more) before air quality modelling can begin. Prognostic mesoscale models have the ability to construct meteorological fields in areas where little or no observations exist. The Regional Atmospheric Mesoscale Model (RAMS), using a fine grid spacing of 1 km, was used to simulate meteorological data for use with the CALPUFF dispersion model in near field analysis. Three five-day periods of moderate to high SO_2 concentrations in a small area surrounding Prince George B.C. in 1999 were used to test model performance.
The research demonstrates that RAMS was able to simulate the valley type flow around Prince George reasonably well when using only the National Centers for Environmental Prediction (NCEP) coarse gridded datasets for initialization. CALPUFF Dispersion estimates using the RAMS fields were as good or better than estimates determined using the data from three surface and one upper-air meteorological stations within the test domain.

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1. Introduction

The amount of industrial activity and its proximity to residential development make air pollution a concern in Prince George (e.g. Ministry of Environment, 2001). Prince George is situated in and around the Fraser valley at the confluence of the Nechako and Fraser rivers. The valley at this location widens into an area locally referred to as the ‘bowl’. The steep sides of the river valley shape the wind flow around the city and provide shelter from the regional winds which occur over the plateau at higher elevations. When certain meteorological conditions develop, pollutants emitted into the airshed become trapped in the valley leading to poor air quality (ibid.).

Air pollution monitoring has been instrumental in managing industrial emissions in the past. The use of dispersion modelling has been limited however, since most regulatory models (those accepted by governments and used to aid decision making) rely on simplifying assumptions that can lead to unrealistic predictions, especially in regions without uniform topography (e.g. Scire and Robe, 1997). These models assume steady conditions and apply just a single wind vector to the entire modelling domain (e.g. Godfrey and Clarkson, 1998). Some newer dispersion models being proposed for regulatory use now have the ability to better represent conditions in areas of complex terrain. The CALPUFF (California Puff Model) modelling system is one such model. By accounting for spatial variability in the meteorological fields, CALPUFF can model more sophisticated circulations such as fumigation, slope flows and stagnation (Scire *et al*, 1999a).

The CALPUFF system has a meteorological model component called CALMET (California Meteorological Model) that is able to incorporate topographical features and upper air conditions in addition to the surface winds from several sites when creating its wind fields. The CALPUFF model is currently being evaluated by the United States

Environmental Protection Agency (EPA) and other bodies for its potential to realistically model conditions in areas of complex terrain (e.g. U.S. EPA, 1999).

With the ability of the newer dispersion models to utilize more comprehensive meteorological data, the dispersion modelling community has expressed interest in the possibility of using mesoscale model fields to increase the accuracy of dispersion predictions, especially in areas where a scarcity of meteorological observations exists (Robe and Scire, 1998). A mesoscale model, by solving the governing atmospheric equations at regular time intervals, is able to resolve both regional and (by telescoping to smaller areas) local circulations (Pielke *et al*, 1992).

The Regional Atmospheric Modeling System (RAMS) is a mesoscale model ideally suited for this purpose. The RAMS user has direct control over many of the schemes and parameterizations used to model the atmosphere (Cox *et al*, 1998a). With little or no local data, RAMS is able to produce modelled meteorological fields that a dispersion model such as CALPUFF could use in place of observations.

The purpose of this study is to test the effectiveness of using RAMS with the CALPUFF system to model dispersion in complex terrain where little or no meteorological data are available.

1.0.1. Research Objectives

The question of whether the merger of RAMS and CALPUFF provides effective dispersion modelling in the Prince George airshed is broken into 2 separate parts to facilitate a greater understanding of the successes or failures of the modelling scheme. The two reseach objectives are:

- To assess the use of RAMS fields in producing high quality CALMET meteorological fields.
- To assess the use of RAMS fields leading to high quality CALPUFF pollutant concentration estimates.

2. Atmospheric Modelling

2.1. Introduction

Historically there have been markedly different schemes used to model atmospheric circulations, with the approach taken depending mainly on the scale(s) of motion one hopes to resolve. The initial impetus behind atmospheric model development was the need to forecast the synoptic-scale (on the order of 10^3 km) and mesoscale (on the order of 1 km) circulations that determine weather. The meteorological observations required to initialize a weather prediction model can be spaced thousands of kms apart, while still allowing enough information for the model to perform well. This type of atmospheric model is termed ‘prognostic’, because of its ability to predict the state of specific meteorological variables in the future. Weather prediction with a prognostic model does not have to be overly concerned with smaller scale motion, such as the boundary layer scale (on the order of 10^2 m). A prognostic model can derive a great saving of time by ignoring these smaller scale motions; the number of calculations required to advance the meteorological fields to a future state is reasonable, as opposed to being computationally ‘expensive’ otherwise (Stull, 1995).

Dispersion modelling for regulatory purposes typically involves analyzing past meteorological conditions for periods up to a year. Accurately resolving smaller scale motions, particularly local winds at and near the earth’s surface, is crucial in determining the dispersion of airborn pollutants (McQueen *et al*, 1995). Before using a modern dispersion model to conduct an air quality assessment of an area, data (wind and atmospheric stability information) from several surface meteorological stations in the area would have to be obtained. This could involve installing several meteorological stations, if none were present in the area. With the data from these stations, the model interpolates and extrapolates the observations to yield the complete fields required at a given time. The dispersion model, or rather its component meteorological model, is termed 'deterministic', since it doesn't have the ability, or need, to predict values in the future. Since each area has its own particular landscape features that uniquely modify the regional wind, recent meteorological models put the greatest emphasis on parameterizing the influence that complex terrain has on local flow (e.g. Scire *et al*, 1999b). The deterministic framework of these models allows for the construction of the meteorological fields with far fewer calculations than a prognostic model would need. Dispersion models therefore are able to run on a simple personal computer, instead of the high performance computers typically used for prognostic models. The effectiveness of a dispersion model is linked to the number of meteorological stations available to use in an area of interest.

2.2. Prognostic (Mesoscale) Models

Although some prognostic models are designed to model a specific scale of flow, there are several mesoscale models in use that have the ability to model nearly all scales of motion. The Regional Atmospheric Modeling System (RAMS) is one such model (Pielke *et al*, 1992). Models such as RAMS are considered research models, because they have numerous optional physical algorithms. Each model is actually a system that incorporates many separate, stand-alone components that are models in themselves (e.g. Cox *et al*, 1998b). This 'plug compatibility' facilitates both usefulness in research, and ease of changing or adding model features.

Like all modern atmospheric models, prognostic models utilize a grid system to represent the section of atmosphere being studied. The grid points are located at regularly spaced intervals throughout the domain. Each grid point contains the average value of a variable for a volume of the surrounding air, or 'grid cell' (Stull, 1995). The operator specifies what horizontal and vertical dimensions each grid cell is to have. The length of time a model run takes on a computer is strongly linked to the size of the domain being modelled, and the grid cell sizes within. The reason general circulation models (GCM's) are able to model atmospheric motions around the entire Earth is because of their typically large grid cell volumes. The drawback in using large grid cells however is that smaller features in the atmosphere are not resolved.

To forecast what value certain meteorological variables will have a short time in the future, the equations describing atmospheric evolution must be integrated. These non-linear, partial-differential equations are based on dynamics, thermodynamics, mass continuity and conservation of variables such as moisture. The equations are not analytically solvable, and approximations must be used to determine solutions. While early forecasting techniques involved simplifying these equations in order to find exact analytical solutions, numerical methods such as finite differencing are now used. A finite differencing scheme approximates a differential equation with a set of algebraic difference equations for values of the tendencies of various field variables at each grid cell. The tendencies are determined by solving the difference equations. By extrapolating the tendencies ahead in time by a small increment, an estimate for values in the next time interval are obtained. The process would then repeat for the next time step (e.g. Holton, 1979).

Mesoscale models such as RAMS solve the full set of equations (called the 'primitive equations') with very few restrictive simplifications (Cox *et al*, 1998a). These equations are supplemented with a selection of parameterizations for those processes that are able to influence atmospheric evolution at scales smaller than the model is able to resolve. These include solar and terrestrial radiation, moist processes such as cloud development and precipitation, kinematic effects of terrain, cumulus convection, sensible and latent heat exchange between the atmosphere and the surface and turbulence. To acknowledge the considerable influence the surface can have on the atmosphere, the surface itself is modelled with multiple soil layers, vegetation, snow cover, canopy air and surface water (Walko and Tremback, 1999).

Observational data analysis is a large component of any atmospheric model. Raw data needs to be processed before its use so that errors or problematic gradients do not lead to imbalanced numerical conditions (Stull, 1995). If observed winds are not in balance with the model temperature and pressure fields that are used to determine the theoretical winds, numerical instability can result in the model 'blowing up' (producing nonsensical fields). It is therefore common for prognostic models to contain separate packages that perform the analysis (called 'objective analysis') required to assimilate meteorological observations to the model grid. Commonly this is known as four dimensional data assimilation (4DDA). The first three dimensions are spatial and the fourth dimension is time, since a model typically requires both an initial determination of the atmospheric variables from which to start, and boundary conditions to constrain the future numerical predictions at the grid boundaries. Because it is very common for a research mesoscale model like RAMS to be used to model time periods in the past, these boundary conditions usually are new observations assimilated to the model grid in the future of the model start. Since this analysis procedure involves smoothing and dynamic balancing of the available data, the produced fields can have values that differ from than the actual values at the observation sites (Walko and Tremback, 1999).

For the first stage of the data analysis procedure, models such as RAMS and MM5 usually access the global gridded datasets that are routinely produced by the National Meteorological Center (NMC) in the United States, or the European Center for Medium-range Weather Forecasting (ECMWF) which are archived and freely available through the internet. These datasets are typically defined on a global scale with a grid spacing of 2.5° latitude by 2.5° longitude on a set number of pressure levels in the vertical. These data are accessed for the area being modelled, and are interpolated to the vertical coordinates of the model grid (e.g. Pielke *et al*, 1992). This information alone is enough to set up the initial conditions and the future boundary conditions for a model run. If radiosonde (which produces a vertical profile of the atmosphere) and surface station observations are available, they can be blended into the objective analysis fields by using weighted averaging.

Once the initial condition fields and the boundary condition fields are generated, the model begins its run. The last task of the 4DDA system is to ensure that model predictions do not stray too far from the large-scale analyzed fields in the future of the start time.

Typically, Newtonian relaxation (commonly known as 'nudging') is used to force model variables to approach the values of the objectively analyzed fields. Nudging adds an extra tendency term to each prognostic equation, which pushes the predicted variable towards the available observation. In general, this is constructed as

$$\frac{\partial x}{\partial t} = F(x) + N(x, y, z, t)\,(x_0 - x), \tag{2.1}$$

where x is the model variable, F is the model's physics, N is the nudging weight function and x_0 is the observed value of the variable (Pielke *et al*, 1992). Nudging can occur at the lateral boundaries, the center, and the top of a model domain; with the influence of the function being set by the operator.

In instances where high model resolution is required, for example when smaller scales of motion need to be revealed, grid nesting can be used. A nested grid, with higher spatial resolution, occupies a region within the domain of its coarser 'parent' grid. Any number of nested grids may be used, with the only practical limit being available computer memory. The use of nested grids greatly increases the number of calculations the computer must perform during a model run. This is because a smaller grid spacing necessitates a much smaller interval of time that the model is able to 'step ahead' when calculating future variable values. The model must take several smaller time steps in its calculations for a nested grid for every time step taken for its parent grid. Telescoping sequences are possible where parent grids are nested within coarser grids themselves. For RAMS, there is two-way communication of all prognostic variables between a nested grid and its immediate parent (Walko and Tremback, 1999). Fine grid values are averaged to replace the coarse grid value which they surround.

2.3. Dispersion Models

Pasquill, in his ground-breaking article "The Estimation of the Dispersion of Windborne Material" (1961) used fluctuation statistics to predict downwind concentrations of released materials. He also proposed a "practical system" that could be used when the necessary data on the local wind fluctuations were not available. Since data of this type and quality

were not available (and still are not in many situations today), it was this practical system that received attention. Pasquill's system allowed for the calculation of the crosswind and vertical spreading of the pollutant plume based on the stability of the atmosphere and downwind distance from the source (Turner, 1997). Pasquill's work led to the development of practical dispersion models that could be tailored for use on a computer.
The classical treatment of dispersion involves a solution to the mass conservation equation (Wilson, 2000):

$$\frac{\partial C}{\partial t} = -\bigtriangledown \cdot (U\,C) \tag{2.2}$$

with U being the wind vector, and C the pollutant concentration. Although numerical techniques could be applied to solve this equation, early air quality models had to consider computational resources, and so a rigourous approach wasn't feasible. Equally as important, many terms that would arise from such an analysis could not practically be dealt with (Zannetti, 1981). By assuming a steady, homogeneous wind, a general solution can be developed for this equation. This solution is the well known Gaussian equation:

$$\overline{C}(x,y,z) = \frac{Q}{2\pi u \sigma_y \sigma_z}\, exp\left[\frac{-y^2}{2\sigma_y^2} - \frac{z^2}{2\sigma_z^2}\right], \tag{2.3}$$

Here, Q is the pollutant emission rate. The pollutant is considered to be released as a continuous plume with characteristic standard deviations σ_y and σ_z that are dependent on atmospheric conditions. The variable u is the magnitude of the wind vector. A variety of methods are used to determine the σ values. Pasquill's method, mentioned earlier, was the first such method, and is still commonly used today. Other methods utilize turbulence measurements (wind fluctuation) when available, or statistical profiling when not (Weil, 1985). The many different models that utilize the Gaussian equation (albeit in different forms) are collectively known as Gaussian Plume models since they treat effluent in the fashion of a spreading plume.
Many atmospheric dispersion models are based on the Gaussian Plume model (Egan and Vaudo, 1985). Early Gaussian models were characterized by the way their most crucial

components, σ_y and σ_z were treated. Although it was clearly recognized that these models had limitations, it was an approach that was accepted for several reasons. Understanding of turbulent dispersion was acknowledged as weak and so a mixture of theory and empirical structure seemed appropriate. Early experiments had shown that a continuous source produces a distribution that roughly follows a Gaussian shape, especially in the horizontal dimension. Finally, computers were not overly taxed, and the lack of inherent complexity allowed for confident generalization of model output. (Zannetti, 1981).

Early plume models, such as the Industrial Source Complex (ISC), have been useful for determining maximum ground level concentrations (GLC's) of single, elevated sources. These models, because of their simplicity, needed very little input data to operate. Surface wind measurements (e.g. airport wind measurements) and stability classification were sufficient. The surface wind speed would typically be extrapolated to the release height by using a power law profile of the wind. The influence topography has on wind was ignored, and the one wind vector was used throughout the modelling domain. ISC determined the concentration at a large number of surface points ('receptors'), often spaced in regular angular positions and distances from the source. Concentration values from 1 or 24 hour averaging times would then be analysed. Plume models were not expected to locate the actual maxima locations, because of the incomplete representation of the wind, but the magnitude of the modelled maxima could be reasonably accurate (Boubel *et al*, 1994).

Plume models are not able to represent temporally and spatially changing conditions. To extend the applicability of the Gaussian approach, air quality researchers realized that existing models would have to be modified to treat non-stationary and non-homogeneous conditions (e.g. Zannetti, 1981). As well, early models assumed flat, smooth terrain. The influence of topography on dispersion could also not be ignored if greater model accuracy was desired. When dealing with irregular topography, the application of the standard Gaussian equation could only be expected to yield the upper limit of concentrations likely to occur (Turner, 1994). As an early attempt to account for topography, the original ISC terrain algorithm simply removed all terrain features, or parts of features, that were higher than the source height (Scire et al, 1999a). This effectively limited the use of the model to those areas where all receptors would be at lower elevations than the source(s). Later models were more refined, modelling the flow parallel to the terrain slope when the receptor was lower in elevation than the source. When the receptor was higher, the flow would either go over the obstacle (ie hill), around it, or both. When a steep obstacle restricted horizontal dispersion, complete plume reflection was modelled, similar to the case of a plume impinging on the ground. Newer models have continued using this approach, although in a more rigourous fashion.

Modern Gaussian models contain quite an exotic mixture of analytical algorithms and empirical constructs. Because much work has been done with Gaussian models since their adoption by the U.S. Environmental Protection Agency (EPA), newer models allow the user to choose between different numerical or empirical schemes (e.g. Scire *et al*, 1999a). As early as 1975 (Ludwig *et al*, 1977), practical Gaussian models were being constructed that attempted to deal with many of the early plume models' shortcomings.

One of the early models, the Complex Terrain Dispersion Model (CTDM) uses a dividing streamline approach to deal with large obstacles. The flow is considered to be made up of two layers; the upper layer has enough energy to transport a fluid parcel over the obstacle, and the lower layer is confined to travel around the obstacle (Scire *et al*, 1999a). Each resolved obstacle in the domain is evaluated by determining the lowest height at which the kinetic energy of the incident flow just balances the potential energy that would be gained by lifting a fluid parcel to the top of the obstacle. Pollutant in the upper layer then experiences an altered rate of diffusion.

Dispersion models evolved into a system where the region of interest is divided into grid cells. A grid cell is a portion of the domain being modelled that has spatially uniform characteristics. Topographical height for example would be a constant value in a grid cell, based upon an averaging of the landscape within the cell. Each cell would have one value for the meteorological variables considered important (or available) for determining the dispersive ability of the atmosphere at that time. Goodin et al (1980) described a terrain approach that was adopted by several models, including CALPUFF. The first step is to specify the region of interest and grid cell sizes. The procedure would then incorporate all surface and upper air data available, which are used to specify initial values for each grid cell. If little or no upper air data are obtainable, the user has the option to construct velocity profiles, using some assumed distribution such as a power law, as input into the model. The wind velocity field would then get a final adjustment so that anomalous divergence is minimized. The surface wind field is created by interpolating and extrapolating the measured data to the gridded domain. Typically, an inverse distance-squared weighting is used, so that an observation closer to a specific grid point gets greater consideration. Large terrain features (ie mountains) are simulated by utilizing barriers to flow during the interpolation procedure.

Early into the development of complex terrain schemes, their algorithms approached a size rivalling those of the dispersion models themselves. It has been common for several years now to have meteorological models as stand alone programs whose output can be directly incorporated into a dispersion model. CALMET is the meteorological model within the CALPUFF dispersion modelling system. A meteorological model such as CALMET is considered “deterministic” since it interprets and interpolates data instead of predicting future values. The developers of these deterministic models however have claimed respectable performance when comparing wind fields with those generated by prognostic forecasting models (e.g. Robe and Scire, 1998). It is becoming more common for these meteorological models to possess the ability to accept gridded ‘data’ from the prognostic models for those conditions when very little local data can be obtained (e.g. Scire *et al*, 1999b).

The development of 3-dimensional meteorological models such as CALMET was a huge step towards extending the applicability of Gaussian diffusion models to non-stationary and non-homogeneous conditions. Dispersion models could now accept data from more than one location and more realistically represent dispersive conditions in different locations throughout the area being modelled. However, to benefit from the increased data resolution, the pollutant could no longer be viewed as a continuous plume. In particular, the “segmented plume” scheme and the “puff” approach have been applied to pseudo-steady-state conditions. These two methods break up the plume into independent elements (segments or puffs) that are individually tracked through a temporally and spatially varying meteorological field. Within the segment or puff, Gaussian statistics determine the concentration levels. Although the Gaussian equation is still applied, most modern regulatory models are considered “modified Gaussian” because they use this disjointed approach (Yadav and Sharan, 1996).

Zannetti (1981) claims that the most obvious way of treating non-stationary conditions, in either effluent or meteorological conditions, while maintaining the Gaussian approach, is to represent the emission of pollutant with the puff method. A puff is released each sub-interval, containing all of the mass emitted during that portion of time. By modelling a plume by a series of fictitious puffs, each having σ’s governed by Gaussian theory, a reasonable approximation of the physical problem is obtained, while also allowing for changing conditions. Justification is given for this claim by the fact that puff models accurately reproduce plume model results under steady state conditions (Ludwig *et al*, 1977).

All puff models give considerable attention to puff spacing. Especially in the past, modellers had to consider the balance between accuracy and computer time; generating more puffs generally meant better representation, but also meant further taxing of computer resources. Early studies showed that individual puffs released from a source could not have their centerlines separated by more than $2\sigma_y$ without unacceptable error. Ludwig *et al* (1977) use

$$N = u \cdot \frac{P}{d} \tag{2.4}$$

to determine the number of puffs to be generated (N) each time period. Here, puff generation is proportional to the wind speed at the source (u), with P being the period over which the puffs are generated, and d the minimum acceptable puff separation. The frequency of puff release increases during higher winds. To save on cpu time, puffs are either ‘purged’ or ‘merged’ when appropriate. A puff is purged when it either leaves the area of interest, or becomes so weak its contribution is negligible to receptor sites. Two puffs are merged when their separation distance is less than a critical value (typically one

σ). The merger produces one puff that contains all of the mass of the two, with σ values and center location determined by averaging.

Several puff models in use today follow the general method outlined above - CALPUFF being one. CALPUFF also has a ‘slug’ algorithm that the creators claim is effective at dealing with weak wind conditions (Scire *et al*, 1999a); a serious shortcoming of the plume models (Harrison *et al*, 1990). A slug is essentially a larger puff that is stretched out in the along-wind direction. A slug can be considered a group of overlapping puffs, having very small separation distances. Each slug is free to evolve independently in response to local conditions.

In contrast with the earlier Gaussian Plume models, puff models now have many choices or ‘switches’ that the user has to choose before operation. The setting of some switches depends on the prevailing meteorology; other switches however can be more difficult to decide upon. There are also interpolative parameters to be set that would differ depending on geographical location and availability of data. These choices are not as numerous and crucial as for a prognostic model such as RAMS, but still represent a serious consideration when analyzing results.

The fact that dispersion studies typically analyse a much longer time period than a mesoscale model would be applied to (one year versus a week), has prevented air quality researchers from using a model such as RAMS in the past. Recently, increases in computer speed and capacity have made this problem far less significant. The United States’ Environmental Protection Agency (EPA) now considers the future of air quality modelling to involve the general acceptance and use of sophisticated mesoscale meteorological models (U.S. EPA, 1999). This mandate is reflected in newer models such as CALPUFF that are able to use mesoscale model output with little modification.

Some examples of the use of mesoscale model output in operating dispersion models can be found in the literature. However, Uliasz and Pielke (1998) claim that the dispersion modelling community is not taking sufficient advantage of mesoscale model fields. They are primarily referring to the large-scale output fields that are readily and freely available from research groups within North America.

Recent dispersion studies have indicated that fine mesoscale model grid spacings must be small enough to properly resolve local topographical forcing. McQueen *et al* (1995), when researching the use of the RAMS model to support air quality forecasting in the Susquehanna River valley of Pennsylvania, determined that horizontal grid spacing must be 2.5 km or less to account for the influence of terrain in that area. Barna *et al* (2000) combined Mesoscale Model 5 (MM5) fields with the CALMET model to produce the meteorological fields needed for an ozone study of the Pacific Northwest (a region including Washington, Oregon and southern B.C.). Although obtaining relatively good agreement with observations, the authors noted that the 5 km spacing of the innermost MM5 model grid failed to capture all of the complexities of the wind patterns in some areas of the domain. Other studies have found similar results (e.g. Earth Tech, 2001). There remains considerable interest in the modelling community of the possibility of using mesoscale model output to improve dispersion calculations. To date, studies involving this type of merger have been on regional rather than local scales, necessitating innermost grid spacings of 2.5 km or greater. There is a need to apply this type of modelling to smaller scales to determine whether improvements are attainable and if application to regulatory modelling is feasible.

3. Methods

3.1. Overview

The use of the RAMS mesoscale model was investigated as a source for meteorological information required for the operation of the CALPUFF dispersion modelling system. RAMS was used to generate meteorological station ‘data’ throughout the modelling area. A 600 km^2 domain including Prince George and its surrounding area was chosen in this study because it is an ideal testing ground for dispersion modelling. Prince George is situated in and around the confluence of the Nechako and Fraser Rivers. The Prince George bowl and adjacent river valleys constitute moderately complex terrain which suitably challenges modelling efforts. This area also possesses a significant network of meteorological and pollutant monitoring stations, providing the opportunity to thoroughly test model predictions from both CALMET and CALPUFF. SO_2 was modelled since it has a limited number of point sources in the area that are relatively well-defined (e.g. Ministry of Environment, 2001).

The models were run over three five-day periods representative of the calm, stagnant conditions usually associated with air quality episodes in Prince George. All three periods occurred in 1999; this year was chosen because data from six surface meteorological stations were available to use, a greater number than in previous years. The locations of the University, Plaza, Prince George Pulp, Airport, Northwood and Glenview surface stations are shown in Figure A.1. Two of the 3 periods chosen (during January and April) contained some of the highest 1-hour and 24-hour concentration levels for the year, although for both periods these levels were not high throughout all 5 days. The third period chosen was in June. These 5 days possessed calm conditions, but also some light precipitation. High concentrations were not experienced at 3 of the 4 SO_2 monitoring locations (also shown in Figure A.1). There were no prolonged periods of high SO_2 concentrations during 1999.

RAMS, using NCEP fields for initialization, was used to simulate surface and upper air meteorological fields (most importantly wind) that were treated as if they were true observations in the operation of the CALMET meteorological model. The RAMS derived CALMET fields were then used to operate the CALPUFF dispersion model to predict SO_2 concentrations during the three test intervals. Although there are other significant pollutants released into the Prince George region, SO_2 was analysed because its sources are well understood, its potential chemical reactivity in a dry atmosphere is minimal over short time periods (D. Fudge, personal communication, 2001) and it is monitored at four sites within the airshed.

3.2. Grid Structure

3.2.1. RAMS

A domain with three nested grids was used for RAMS modelling (see Figure A.2), with each domain centered on Prince George. This scheme is intended to correctly capture the regional forcing as well as the smaller, local-scale features; both are significant in determining mesoscale circulation (McQueen *et al*, 1995). Table 3.1 shows the extent and resolution of the three nested RAMS grids used in each model run.

Grid	Horizontal Spacing (km)	Number of cells in x	Number of cells in y	Total Domain x and y (km)	Vertical Spacing (m)	Vertical Levels	Stretch Factor
1	16	100	100	1584 x 1584	25	40	1.14
2	4	50	50	196 x 196	25	40	1.14
3	1	62	62	61 x 61	25	40	1.14

Table 3.1
RAMS Grid Sizes

Although the size and resolution of the three grids can be varied, the coarse grid must be large enough to resolve the significant synoptic features influencing regional flow, and the innermost grid must have fine enough resolution to adequately represent the effect local topography has on winds near the surface. Grid spacing of 1 km was chosen for the smallest grid. The spacing for the coarser ‘parent’ domains were 4 km and 16 km, following advice indicated in the RAMS manual (Walko and Tremback, 1999).

The number of vertical levels in the modelling domain, or height of each grid cell, can also be specified. Previous studies have shown that vertical spacing in a mesoscale model run must be 25 m or less near the surface in order to properly account for terrain forcing in complex topography (e.g. McQueen *et al*, 1995). Atmospheric variables become more homogeneous in layers further from the surface, therefore it is common practice to increase the vertical spacing of the grid cells at higher levels to save on computer time (e.g. Guan *et al*, 1997). Bossert and Poulos (1993) set their RAMS vertical grid spacing to 10 m at the surface for the steep terrain around Boulder Colorado. The Prince George region in comparison possesses moderately complex terrain, so 25 m spacing was chosen, along with a stretch factor that gradually increased this spacing with height above the surface. The top of each domain was at 19 km above sea level. See the RAMS control file in Appendix C.7 for more details.

3.2.2. CALPUFF

Although CALPUFF has the capability to model regional scales, the Prince George bowl and surrounding area was the focus of this study. This is primarily because all monitoring data available to test model output comes from locations near or within the city limits. A domain of 49 x 49 square grid cells, with a horizontal spacing of 500 m was used for all CALMET and CALPUFF runs. Each run also had 8 vertical levels, spaced closer together near the surface, up to a maximum height of 3500 m (see CALMET/CALPUFF control files in Appendix C.8 and C.9). Levels above this height are not important to the eventual SO_2 calculations, because they are in the free atmosphere and to a large extent do not interact with the levels below (Stull, 1995). A dataset with averaged topographical heights for each grid cell was used to represent the terrain. Figure A.1 displays the CALMET/CALPUFF domain, with topography, and the locations of the meteorological and air quality monitoring stations. The locations of the significant SO_2 sources are also shown.

3.3. Model Initialization

3.3.1. RAMS

In this study, RAMS was used for both its analysis and forecasting abilities. RAMS objectively analyses meteorological data into gridded values for each of its three domains and uses these periodic fields to guide or ‘nudge’ its predictions. RAMS has the ability to combine several meteorological data sets in its data analysis procedure (Walko and Tremback, 1999). The primary input for this model is the global gridded datasets constructed from a state-of-the-art analysis/forecast system that assimilates surface and upper air observations from around the world. The gridded fields used in this study originate from the NCEP (National Centers for Environmental Prediction) Reanalysis project, and are provided by the NOAA-CIRES Climate Diagnosis Center, Boulder Colorado USA, from their web site at http://www.cdc.noaa.gov. The resolution of these datasets is quite coarse, with a horizontal spacing of 2.5° latitude by 2.5° longitude and 17 pressure levels from 1000 hPa to 10 hPa. Averaged meteorological variables are present for each grid cell in a four times daily format, representative of instantaneous values at the reference time. Although separate surface and radiosonde data can be blended with these fields during RAMS initialization, the use of the NCEP fields alone was the focus of this work (thus simulating data-sparse conditions). As a RAMS run progresses from its starting time, its forecasts are nudged towards these analysed fields.

RAMS also requires the surface characteristics of each nested domain to be determined before a run commences. Each grid must establish the topographical heights, sea surface temperatures (if applicable), soil type, soil moisture, vegetation and roughness for each cell. The information required for this procedure is typically obtained from datasets available from the Atmospheric Meteorological and Environmental Technologies (ATMET) site at http://www.atmet.com and was done so in this study. Although the user may acquire separate, idealized or higher resolution data sets to use in their stead, only the insertion of a separate topographic data set was investigated in this study.

All mesoscale models have options related to the type of data that is available for ingestion. Because RAMS is more of a research model than many others, it also has numerous optional physical algorithms that must be considered before commencing a run (Cox *et al*, 1998b). In addition, several parameters that influence RAMS calculations need to be set. The choices used in this research were influenced by previous modelling studies of a similar nature in the literature and anecdotal remarks from other RAMS users. Once the model settings were decided upon, the same configuration was used for each of the three periods. The RAMS initialization file used to begin a run is shown in Appendix C.7.

The 'REVU' utility, included with the RAMS package, was used to extract the modelled variables for use with the CALMET meteorological model. REVU allows the user to extract all information normally found in a radiosonde profile; a C^{++} program was written that used these modelled variables to construct high resolution vertical soundings in a format CALMET readily accepts. These modelled soundings were constructed at 13 selected locations throughout the Prince George area. The profiles were generated every two hours throughout the 5 day study periods, although CALMET has the ability to accept data every hour. Having RAMS generate output fields every two hours already necessitated a significant amount of data storage and seriously taxed the computer facilities available.

3.3.2. CALPUFF

For meteorological input, CALMET requires hourly values of wind speed, wind direction, cloud cover, ceiling height, surface pressure and relative humidity from one surface station, and a vertical profile of wind speed, wind direction, temperature, pressure and height twice daily from one upper air station. These data are routinely observed by MSC (Meteorological Service of Canada) surface and upper air stations. Prince George has both an MSC surface and upper air station (Airport and ZXS respectively, see Figure A.1) within its airshed. CALMET allows missing values of temperature, cloud cover, ceiling height, surface pressure and relative humidity for a surface station as long as these values are available from at least one surface station each hour (Scire *et al*, 1999b). This allowed the temperature and wind data from one or more of the five non-MSC surface stations within the modelling domain to be utilized. The Northwood, Prince George Pulp, Plaza and Glenview stations are operated by the British Columbia Ministry of Water, Land and Air Protection (formerly the Ministry of Environment, Lands and Parks) and University is managed by the Atmospheric Science Group at the University of Northern British Columbia. The locations of the 5 non-MSC stations are also shown in Figure A.1. CALMET permits any number of surface and/or upper air stations in or near the domain; and upper air data can be as frequent as every hour, as previously mentioned.

As with RAMS, CALMET also requires geophysical data for each grid cell; terrain elevation and land-use category must be provided and other parameters are optional. Surface roughness, albedo, Bowen ratio, soil heat flux and vegetation leaf area index all have default values dependent on the land-use category of each grid cell (Scire *et al*, 1999b). The intent of this study was to test the CALPUFF system as it is commonly used in practice; therefore elevation and land-use category were the only parameters specified for the domain.

There are a considerable number of switches the operator needs to set for both of the CALMET and CALPUFF modules. Most however have default settings and these were chosen for many of the options. In situations where no default settings were available, or where default settings were found to be inappropriate, test case settings were used. Test case settings are those that were used by the model's developers when testing the model in different regions. Correspondence with other CALPUFF users, and with one of the model's architects was also considered in making these decisions.

One significant setting to note is the ‘Kinematic Effects of Terrain’ option that was switched off for this work. This algorithm is meant to compute a terrain-forced vertical velocity through an analysis of divergence in the initially developed wind field. Although the default setting was to have this component activated, sensitivity tests showed that it periodically led to unrealistically high wind speeds at some station locations in Prince George. Evidence that this feature can lead to problems in some situations was confirmed by another CALMET user (D. Fudge, personal communication, 2000). This option was turned off, following the advice of Joe Scire, one of the model’s creators.

The three 5-day periods in 1999 that were previously discussed had significant SO_2 concentrations at one, some or all of the four monitoring sites in Prince George. For each period, three CALMET runs were conducted using the twice daily radiosonde profile at ZXS; the first with just the one MSC surface station (Airport), the second using three surface stations (University, Airport and Northwood) and the third utilizing all six available surface stations. These three configurations are intended to represent CALMET’s performance when using the minimum amount of data required for a run, an amount typical of many modelling situations, and a “best case” situation where abnormally high data resolution exists. They will be referred to as the “CALMET-1”, “CALMET-3” and “CALMET-6” models throughout the remainder of this thesis.

A CALMET run was also made for each of the 3 periods using the one required MSC surface station at the airport and a number of RAMS generated surface and upper air stations throughout the domain. Although it was initially intended to use the full vertical profiles from RAMS at all 13 chosen locations, it was discovered that RAMS at times did not accurately model some of the important boundary layer features through the lowest levels in the valley (see Figure A.6). In particular, the shallow, strong inversions that commonly occur through the lowest 350 - 400 m above the surface in the bowl, although captured reasonably well on occasion, were at times represented as a deeper layer with more moderate stability. As well, the veering of wind with height (clockwise rotation of the wind vector) through the lowest 100 to 150 m was not realistic in some situations. Since SO_2 is released at heights up to 60 m above the ground, and buoyancy commonly

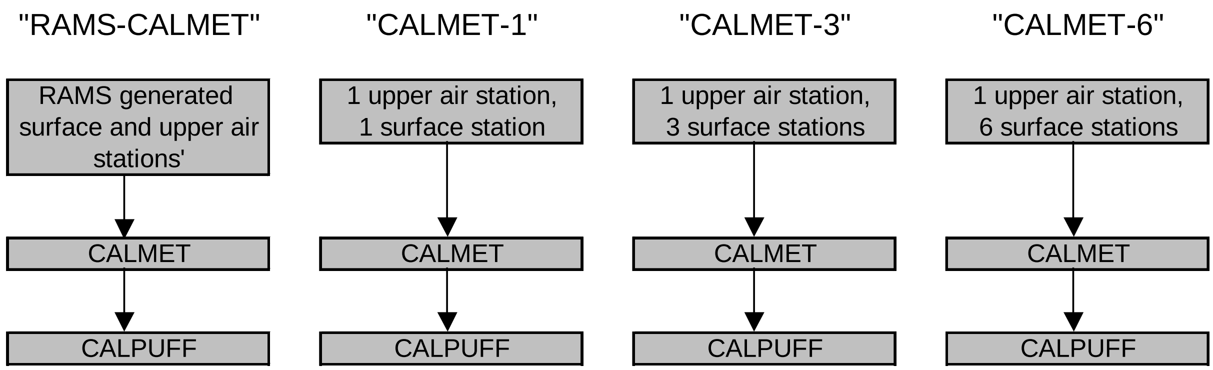

Figure 3.1. Flow chart showing the 4 CALPUFF modelling schemes

carries the plume higher, accurate determination of the winds at these heights is equally as important as those near the surface. It was determined that CALMET's optional statistical profiling method of estimating the wind direction in layers above the surface would be more suitable in the bowl and valley areas. Therefore, as a common procedure for all three periods, RAMS fields were used to construct surface station data at 13 locations throughout the Prince George domain, and just one full vertical sounding at a location on a plateau out of the valley. Five of the constructed surface station sites were at the same coordinates as the 5 non-MSC stations, while the remaining 8 were placed to fill in the 'gaps' remaining in the domain. The solution described here likely did not address the problem with modelling stability. This modelling scenario will be referred to as the "RAMS-CALMET" model.

A CALPUFF dispersion run was then completed using the meteorological output from each of the four models for each period. When discussing dispersion model results, the model name "RAMS-CALMET" will refer to a CALPUFF run that uses the output from the RAMS-CALMET meteorological model. This same naming arrangement will be used with the other 3 CALMET configurations as well. A diagram illustrating the 4 modelling schemes is shown in Figure 3.1. As with CALMET, several CALPUFF switches had to be decided upon before commencing the dispersion runs. Again, default settings were used for most switches. Test case settings were used as guidance for those parameters without default values. CALPUFF was more easily configured than CALMET and suitable dispersion model settings were chosen for the 4 CALMET cases. The initialization files for a CALMET and a CALPUFF run can be found in Appendix C.8 and C.9 respectively. The same CALPUFF settings were used for each of the 4 meteorological model configurations.

3.4. Analysis

Both the modelling results of CALMET and CALPUFF were compared to observations. Because RAMS is a meteorological model, and five of the six surface meteorological stations can be used to validate modelled winds, more effort was spent in assessing CALMET's performance than CALPUFF's. For surface winds, a Root Mean Square Vector Error (RMSVE) analysis was completed for each period. Windrose diagrams were constructed for each station as well, to show the overall wind pattern for both modelled and observed winds. CALPUFF SO_2 predictions for a 1 hour averaging time were graphically compared to monitored values for each monitoring location. Twenty four hour average concentrations were also used in Mean Relative Error (MRE) calculations. Data for the Gladstone location were not available for the April and June periods.

Difference or error measures, in particular the root mean square error (RMSE), are commonly used to evaluate modelled wind predictions (Willmott *et al*, 1985). The root mean square vector error (RMSVE), as described by Cox *et al* (1998b), was chosen to statistically assess surface wind modelling results. RMSVE is calculated by

$$\frac{\left(\sum_{i=1}^{n}\left[(u_p^i - u_o^i)^2 + (v_p^i - v_o^i)^2\right]\right)^{\frac{1}{2}}}{n} \tag{3.1}$$

where u and v are the east-west and north-south vector wind components, n is the total number of observations and the subscripts p and o denote predicted and observed values respectively. A lower score indicates better model performance. The five non-MSC station locations were used to determine the RMSVE scores. An RMSVE value was calculated for RAMS-CALMET, CALMET-1 and CALMET-3 every hour of each modelling period.

An average value for each entire period was also calculated. This analysis was not performed on CALMET-6 since it used the data from all 5 of the observation stations. The scores for CALMET-3 are somewhat misleading, since two of the five surface stations (University and Northwood) were used as input data to this model. Hence the RMSVE scores for CALMET-3 are favourably biased.

Mesoscale atmospheric models can provide an accurate depiction of the evolution of a weather producing system. It is not uncommon however for the modelled timing of systems to be different than observed (e.g. McQueen *et al*, 1995). It should be expected that although RAMS may resolve local circulations accurately, a modelled feature could occur at a different hour than when it occurred in real-time. The use of the highly averaged and smoothed NCEP initialization fields would contribute to this effect. Some of RAMS-CALMET error may be attributable to this time effect. One must also consider the fact that RAMS derived winds are instantaneous values every two hours, averaged through an entire layer (the first 25 m for surface winds). These modelled winds are different in nature than the observed winds that are hourly averages at a specific height above the ground. CALMET modelled winds are based on the observed winds they receive as input, but they too are subject to layer averaging. In general however, CALMET-1 and CALMET-3 winds are more similar in nature to the observed winds than RAMS-CALMET winds are.

A qualitative assessment method was used in addition to the statistical RMSVE scoring. Windrose diagrams visually display wind direction and frequency for a specified period of time at a location. Observed or predicted winds are placed in one of 16 different directional categories, separated by 22.5 degree increments. The percentages of winds in each direction category are displayed in a format that also indicates wind speed. An analysis of these diagrams indicates the degree to which a model captured a significant feature of the observed wind flow, regardless of the actual hours it occurred over.

A more accurate determination of the surface wind field likely leads to a more accurate prediction of SO_2 concentrations. However, simulating the turbulent properties of the atmosphere is also a crucial component to dispersion modelling (Harrison *et al*, 1990).

Winds at higher levels, and boundary layer characteristics can also have a large impact on model predictions, since they largely determine the turbulence fields. RAMS-CALMET, CALMET-1, CALMET-3, and CALMET-6 meteorological output were used to run CALPUFF, each with identical model settings. To visually assess the dispersion results of the first three models, SO_2 concentrations at one hour sampling intervals were graphically compared to observed levels at each monitoring location. CALPUFF output derived from CALMET-6 fields was also used in this assessment as an indicator of model performance under ideal conditions.

In practice, model validation commonly uses a 24-hour sampling interval (e.g. Ministry of Environment, 2000). A table of 24 h concentrations for each model at each monitoring location was used to qualitatively validate dispersion results (in addition to the one hour plots). A statistical measure of the accuracy of the 24-hour concentration values modelled at each monitoring location was conducted. This is a summary score showing how well a model determined the 24-hour concentration values at each site during a five day period. The “Mean Relative Error” (MRE), as described by Harrison *et al* (1990), was chosen for this measure. This parameter is defined as:

$$MRE = \left[\frac{2}{N} \sum_{i=1}^{N} \left(\frac{[P_i - O_i]}{[P_i + O_i]} \right)^2 \right]^{\frac{1}{2}} \tag{3.2}$$

where N is the number of observations, P refers to predicted values and O to observed values. A lower score (expressed as a decimal or a percentage) indicates higher model accuracy. This statistic can exaggerate error when concentration levels are near zero.

4. Results

4.1. Background

Of the six meteorological stations (see Figure A.1), Glenview is probably the most representative of the regional flow in the Prince George area. Being situated on a plateau outside of the Fraser Valley, Glenview station likely experiences little influence from terrain features (Ministry of Environment, 2000). This may be true to a certain extent for University station also; although it is situated on Cranbrook Hill, which likely has some influence on the winds in that general area. The Airport station is partially influenced by the valley. Figure A.16 displays a windrose diagram for Glenview, Northwood, Prince George Pulp and Plaza for the entire year of 1999. Not surprisingly, the orientation and curvature of the Fraser valley appear to have an effect on wind direction for the three lower elevation stations. Notably, a higher frequency of northerly flow occurs for Northwood and Prince George Pulp and of both easterly and westerly for Plaza, as compared to Glenview. The increased northerlies in the valley are likely due to a drainage effect where cold, denser air sinks and moves down the valley, typically at night. The higher frequency of east and west flow at Plaza is mainly due to the curvature of the valley as it expands into the bowl area. Windrose diagrams for the year 1998 are very similar to these 1999 plots. In addition, the 1999 Annual Air Quality Report for Prince George shows that SO_2 levels in the city core are strongly correlated to an easterly flow at Plaza during the same time frames (Ministry of Environment, 2001). The 1998 Report shows a similar correlation. Given the location of the main SO_2 sources (Figure A.1), it appears evident that a light northerly flow down the valley, steered towards the west into town, is a precursor for high SO_2 episodes in the city.

Plots of the NCEP fields over British Columbia were constructed for each of the three test cases (Figures A.3 to A.12). 925 and 500 mb height contours are drawn, along with vector winds. These graphs give a general picture of the evolution of the synoptic scale flow during the three 5-day periods. Windrose diagrams were also plotted to show the overall pattern of the observed and modelled surface winds at each meteorological station site within the Prince George Domain. An exception was made for the CALMET-3 model University and Northwood surface stations since data from these stations were used as input for the model and therefore had windrose plots virtually identical to those observed at the two stations.

In the following analysis of modelling results, the first test period (January) will be discussed in detail, followed by shorter summaries of the other two periods.

4.2. Meteorological Results

4.2.1. Weather Evolution

Figures A.3 to A.5 indicate the weather pattern experienced in Prince George during January 28 to February 1. On January 28 an upper level ridge started to develop over B.C. that intensified and then broke up by February 3. At lower elevations, a weak pressure gradient over the province developed into a broad ridge in the interior that weakened near the end of the period. Observations at local stations showed that the initial southerly flow weakened under the high pressure system and a light northerly flow developed in the valley. Radiosonde data from ZXS (see Figure A.6a) revealed that an inversion developed during the evenings of January 30 and 31, inhibiting vertical mixing. As the upper ridge weakened, wind speeds increased and a more southerly flow was re-established.

The two observed inversions had maximum temperatures aloft that were 7 °C higher than at the surface. In both cases, these layers extended approximately 400 m above the surface of the bowl, as indicated by the early morning sounding. Figure A.6a shows the observed vertical temperature profile of the lowest kilometer above the surface of the bowl on

January 31.

Figures A.7 to A.9 reveal that an upper level ridge also characterizes the April period, but to a greater extent than in the January case. High pressure at lower elevations led to calm winds in the Prince George region, with speeds less than those observed for January on average (Figures A.23 to A.27). A weak northerly flow occurred for a large portion of this 5 day span. Nocturnal inversions developed during April 15, 16 and 17, with greater stability than was observed during the January episode. Figure A.6b shows the temperature profile at 4 a.m. on April 16.

The June period contained a broad high pressure system that extended throughout British Columbia (Figures A.10 to A.12). The prominent upper ridge experienced for the January and April cases also developed in June, although not until the latter half of the interval. Surface winds were very weak in the Prince George region, with speeds lower than during the April case. The northerly valley flow observed during January and April did not develop during this period (Figures A.28 to A.32). These 5 days differed from the previous two cases in that strong stability did not develop overnight and there was some light precipitation. Figure A.6c shows the observed temperature profile at 4 a.m. on June 11, which was similar to the other evenings of this period.

4.2.2. Upper Air Comparison

An example RAMS vertical temperature profile was constructed for each 5-day period to compare with the corresponding ZXS profile (Figure A.6). CALMET-1, CALMET-3 and CALMET-6 each used radiosonde data from ZXS in constructing their meteorological fields and therefore cannot use these vertical profiles to compare to. RAMS had difficulty modelling the Boundary Layer vertical temperature gradient during the evenings for two of the three test cases. During the two evenings in January that had strong stability, RAMS modelled a stable layer extending 500 - 600 m above the surface of the valley, but with roughly an isothermal profile instead of an inversion. Model temperatures above the boundary layer were a better representation of the observed sounding profiles.

During April, RAMS modelled an inversion during the evenings of the 16th and 17th, but not of the same magnitude as observed. Temperatures aloft in the example RAMS profile are a maximum of approximately 4 °C higher than at the surface of the bowl, but this temperature difference in the observed profile is 10 °C. The RAMS temperature soundings during the evenings of the June period were similar in lapse rate to those observed, but the surface temperatures were at times significantly different.

4.2.3. Total Wind Comparison

The Root Mean Square Vector Error for modelled surface winds during the January case for RAMS-CALMET, CALMET-1 and CALMET-3 is shown in Figure A.13. The CALMET-6 model is not discussed here, and is only used as a comparison for dispersion model results. The RMSVE profile for RAMS-CALMET shows large error during the beginning and ending of the period, when local wind speeds were higher and much smaller error during the weak northerly winds of the pollution episode (from hour 48 to 82). CALMET-1 shows an opposite pattern and has much higher error than RAMS-CALMET during the episode. Its error during the beginning of the period is substantially lower than RAMS-CALMET. CALMET-3 has less error than the other two models except during the interval from hour 48 to 82, where its error is similar, but slightly higher, than RAMS-CALMET. CALMET-3 was more consistent than the other two models in its error values throughout the five days.

Figure A.14 shows the RMSVE values for the April period. The RAMS-CALMET values do not follow a discernable pattern during this period as they did for January. The higher observed wind speeds than modelled during the first 24 hours may be responsible for some of the high error initially, but observed winds remained weak throughout the following four days. The CALMET-1 results do not display an obvious RMSVE pattern either, and overall its error is slightly lower than RAMS-CALMET. CALMET-3 has error values consistently lower than the other two models throughout the five days.

The RMSVE values for RAMS-CALMET in June are similar in magnitude to those in the

April period (Figure A.15). The CALMET-1 values are similar to RAMS-CALMET on average, and for the first time CALMET-3 does not have error values clearly lower than those of the other two models.

Table 4.1 shows a simple 5-day average for each model's hourly RMSVE values for each of the three test cases. As indicated earlier, CALMET-3 values are favourably biased since data from two of the observation sites used to calculate RMSVE were used as input to the model.

MODEL	JANUARY	APRIL	JUNE
CALMET-1	1.19	0.78	0.85
CALMET-3	0.66	0.58	0.78
RAMS-CALMET	1.02	0.90	0.90

Table 4.1
Average model RMSVE ($\frac{m}{s}$) for the three 5-day test cases

4.2.4. Windrose Comparison

A windrose plot of observed and modelled winds was made for each of the five surface stations as a qualitative comparison. This comparison was performed to determine whether or not significant attributes of the observed wind flow were captured by a model, regardless of the time of occurrence. In analysing results, distinction was made between those stations within the valley and those outside the valley (at higher elevation).

4.2.4.1. January

Figures A.18 to A.22 show the windrose plots for the January period. RAMS-CALMET had reasonable success in predicting wind direction outside of the valley at Glenview and University. Both modelled stations show a higher frequency of easterly flow than observed, likely caused by the NCEP fields (the fields that RAMS coarse grid values are nudged towards) having a similar pattern (Figure A.17). For observed winds less than 2 ms^{-1}, RAMS-CALMET was quite successful in its predictions, especially at University station. On the average, modelled wind speeds were lower than observed.

CALMET-1 winds had high southerly and low northerly frequencies for Glenview and University. While this resulted in a reasonable prediction for University, it did not for Glenview. The significant northerly flow observed at Glenview was not modelled. CALMET-3 winds matched the observed directions at Glenview closely, with just the infrequent light winds from the east not modelled. Both CALMET-1 and CALMET-3 had an average wind speed very close to that observed for the period.

For the three stations within the valley, RAMS-CALMET was successful in predicting wind direction. The valley's influence on wind direction was obvious, as modelled winds at Northwood and Prince George Pulp were predominantly either northerly or southerly. At Northwood, the model predicted winds from the north at a high frequency; but not as often as observed. Southerly winds were predicted twice as often as observed. At the Prince George Pulp station, the steering effect of the valley produced more of a north-easterly and south-westerly flow than was modelled. The observed winds at Plaza had a high frequency of easterlies, which was captured by the model. The low frequency of westerly winds was represented, but south-easterly winds were predicted that were not observed. In each case, RAMS-CALMET underpredicted wind speed more than it did with the stations out of the valley. This underprediction was more prominent for the higher observed wind speeds near the start of the period.

CALMET-1 had a much higher frequency of southerly winds than was observed at Northwood, and as a result missed most of the observed weak northerly flow. The same result occured at Prince George Pulp. CALMET-3 was better at this station, but still missed much of the northerly flow. It also modelled a significant easterly tendency that was not observed. CALMET-1 and CALMET-3 did not represent the frequent easterly winds observed at Plaza. Both models overpredicted wind speed in the valley, CALMET-1 to a higher degree.

These qualitative comparisons suggest that RAMS-CALMET captured the frequency of the dominant wind directions in the valley moreso than the other two CALMET models. At higher elevations this was not the case. A weakness of the RAMS-CALMET model for this period was in its consistent under-prediction of wind speed. It was surprising that CALMET-3 didn't perform better in its Prince George Pulp and Plaza station predictions, given that it used the observational data from the Northwood station, just a short distance up the valley, as input.

4.2.4.2. April

The windrose plots for the April period (A.23 to A.27) reveal that RAMS-CALMET did not capture surface wind direction as well as it did in January. The lack of northerly flow in the NCEP fields likely was the cause of RAMS modelling predominantly southerly flow outside of the valley (Figure A.17). However, due to the fact that these modelled regional winds were quite weak, RAMS was able to develop some of the observed northerly flow in the valley, likely due to the drainage effect. Both CALMET-1 and CALMET-3 were more successful during this period than in January. Although CALMET-1 did not closely represent surface winds, these plots indicate it did a marginally better job than RAMS-CALMET. CALMET-3 wind frequencies were significantly closer to observations than those from the other two models at the Plaza, Prince George Pulp and Glenview stations.

4.2.4.3. June

The windrose plots for June (Figures A.28 to A.32) indicate that each model had trouble modelling the wind flow for this period. RAMS-CALMET modelled wind direction reasonably well at higher elevations, but in the valley had a much higher frequency of southerly flow than observed. This model again consistently under-predicted wind speed.

The channelling effect of the valley was obvious in its plots for the lower elevation stations, whereas this wasn't the case with the other two models. The windrose plots do not clearly indicate that any one model was better at capturing surface circulation features than the others for this period.

4.2.5. Summary of Meteorological Results

The channelling effect of the valley on the regional winds was captured quite well with the RAMS-CALMET model, even when it had considerable error in wind direction at the higher elevation stations. The error in wind direction for this model was lower in general when the regional wind speeds were low. At these times, the local terrain would likely have a greater effect on wind direction, which RAMS was able to model. During these same intervals, CALMET-1 and to a lesser degree CALMET-3 generally had greater error. RAMS consistently modelled wind speeds lower than observations indicated for each test case. This problem was likely the cause for much of RAMS-CALMET's high RMSVE scores.

Part of the cause of the poor performance of both CALMET-1 and CALMET-3 during the January period may be due to the Airport station data. The archived data at this station are rounded to the nearest single digit, and the wind monitor tends to stall during calm winds. This resulted in a number of zero readings during stagnation periods. The Airport station registered a zero wind speed for a large portion of the weak northerly flow experienced during the January case. This would have some effect on CALMET-3 predictions at both Prince George Pulp and Plaza, and definitely would have a large impact on CALMET-1 predictions at all five stations. Although observed wind speeds at the 5 non-MSC stations were lower during the April and June intervals, zero readings at the airport were not as frequent.

Although the CALMET model itself has a slope flow algorithm, CALMET-1 and CALMET-3 did not represent much of the north-south valley flow observed throughout the 3 test periods. This was surprising for the CALMET-3 model, since it used data from one of the valley stations as input.

4.3. Dispersion Results

4.3.1. Background

High pollutant concentrations are usually associated with low wind speeds and periods of high atmospheric stability (Stull, 1995). A surface high pressure system, with clear skies commonly brings these conditions to the Prince George area. The combination of low wind speeds, a northerly valley flow, and capping inversions at night can cause pollutant levels to increase both in the valley and at higher elevations. However, the mechanisms responsible for high ground level concentrations can differ depending on receptor location. It has been well documented that the diurnal cycle of SO_2 concentration at Plaza has a significant peak during the late morning. This behaviour is likely due to a process called fumigation. This process occurs when pollutant levels build up overnight at higher levels in the atmosphere and are then brought back to ground level once daytime heating removes the inversion layer and mixing occurs (Ministry of Environment, 2001). Sites at higher elevations, such as the CBC location, instead develop higher concentrations as the atmospheric stability increases. The Jail site, at an intermediate elevation, would be subject to both these mechanisms.

4.3.2. Hourly Concentrations

4.3.2.1. January

All four monitoring locations indicated high levels of SO_2 during the five day period in January (Figures A.33 to A.36). Concentrations at Plaza and Gladstone had less variation than at Jail and CBC, and were highest during the third and fourth day (hours 48 to 96) when the overnight inversions created stagnant conditions in the valley. Levels at the two higher-elevation sites came in short bursts with high peak values. This pattern, commonly observed for these stations (Ministry of Environment, 2000), likely is caused by the pollutant plume impinging on the side of the valley, as it either turns westward or continues southward. Although Gladstone is further down the valley from the main sources than the other three monitoring sites, concentrations there were just as high as at Plaza. This indicates that the northerly flow responsible for directing high levels of SO_2 into the city may have continued following the valley, bringing higher levels further downstream.

The CALMET-6 configuration, used to represent the CALPUFF system when having ideal data conditions, was successful at modelling SO_2 levels at three of the four monitoring sites, in general overpredicting levels by a small amount. At Gladstone however, this model seriously underpredicted concentrations for the period.

RAMS-CALMET modelled peak values very close to those observed at Plaza, with the highest levels indicated between 48 and 82 hours. At Jail and CBC, model estimates were higher than observations and higher than the CALMET-6 predictions. Especially at the Jail site, peak concentrations were consistently too high. In contrast, this model under-predicted levels at Gladstone throughout the five days. Only during the interval from 48 to 82 hours did modelled levels approach those observed at this station. In general, these results are not surprising, since RAMS-CALMET missed much of the north-easterly wind flow observed at Prince George Pulp in favour of northerlies. This likely caused a larger portion of the modelled plume to be carried over the valley wall than steered into the bowl. The weaker stability regime modelled by RAMS during the strong, shallow inversions experienced on January 30 and 31 could also have been a cause of the lower modelled concentrations at Plaza and Gladstone.

CALMET-1 had reasonable success modelling levels at Plaza, Jail and CBC during the first 48 hours of the January period, but completely missed the levels that occurred between hours 48 and 82. This was a serious omission, since the highest observations occurred during these days. No appreciable concentrations were modelled at Gladstone during any of the five days. The performance of CALMET-3 was very similar, the notable difference being that estimates during the first 48 hours were higher than those of CALMET-1 at Plaza and Jail.

Overall, the hourly concentration plots indicate the RAMS-CALMET model represented observed SO_2 levels better than both CALMET-1 and CALMET-3 during the 5 days in January. Accurately capturing the northerly valley flow appeared to be a crucial component of modelling dispersion for this period. Because the modelled winds of CALMET-1 and CALMET-3 were lacking much of this northerly flow, each performed poorly at all monitoring sites.

4.3.2.2. April

With the exception of the CBC site, observed SO_2 concentrations were lower during the April period than in January (Figures A.37 to A.40). Data from the Gladstone station were not available during this period. Concentrations remained very low until the third day (at about 50 hours) at each of the three monitoring sites when strong, capping inversions caused levels to increase. Although peak values at Plaza were almost as high as those in January, levels did not remain high between these surges of higher concentration. This was somewhat surprising, since meteorological conditions appeared just as conducive to high SO_2 levels as they did during the January case.

CALMET-6 did not perform as well as it did during the January episode. Although the model represented levels at Plaza reasonably well, it greatly over-predicted levels at Jail all five days and at CBC for the 2nd day (hour 40 to 46 in particular). No high concentrations were modelled at Gladstone until the last day, but monitoring data were not available at this site for comparison during April.

RAMS-CALMET modelled some intervals of higher 1-hour SO_2 levels at Plaza, Jail and CBC during this period, but in several cases not at the same times as when observed. This was expected, since the model did not represent wind direction in the valley as well as during January. This model did not predict significant concentrations at the Gladstone site. Similar to the January case, the lack of north-easterly flow modelled at Prince George Pulp and the weaker stability indicated by RAMS likely are responsible for the lower than observed values at Plaza.

Both CALMET-1 and CALMET-3 generally underpredicted concentrations at the three operating sites during the first 80 hours but better represented observations at Plaza and Jail for the remaining 40. Both models indicated lower concentrations at Gladstone, but higher than what RAMS-CALMET predicted.

4.3.2.3. June

Although June had the lowest wind speeds of the three test intervals, it also had the lowest concentrations observed at the three operating monitoring locations (Figures A.41 to A.44). The atmospheric stability during this period was not as strong as during the other two intervals, likely one of the reasons the air quality was better. On several occasions during this period, each of CALMET-6, CALMET-3 and RAMS-CALMET over-predicted concentrations at the three monitoring sites. CALMET-1 did not show this characteristic. Qualitatively, RAMS-CALMET performed to a similar degree of accuracy as CALMET-6 for the three stations. However, this doesn't indicate that RAMS-CALMET performed well, but instead that the CALPUFF model, in the configuration chosen for this research, generally has a tendency to overpredict concentrations during calm conditions.

Although CALMET-1 and CALMET-3 predicted SO_2 concentrations that were close to the observed levels in many situations, each greatly underpredicted values on occasion. RAMS-CALMET did not underpredict concentrations at Plaza for this period, likely because the RAMS generated soundings were a better match to the actual conditions for these five days (Figure A.6c). Ironically, although CALMET-1 had less observational input than CALMET-3 and CALMET-6, its predictions were closer to observations at the three monitoring sites.

4.3.3. 24 Hour Concentrations

Mean Relative Error scores were used to compare modelled 24-hour average concentration values at the monitoring sites. For the January period, this error calculation used 20 data pairs; 5 24-hour concentrations for each of the 4 operating monitoring sites. For April and June, 15 data pairs were used instead; since there were no observations at the Gladstone site (see Tables 1, 2 and 3 in Appendix B). Table 4.2 below shows the MRE scores for each 5-day period. A lower score indicates better performance. It was evident in performing these calculations that the tendency of the CALMET-1 and CALMET-3 models to seriously underpredict concentrations on occasion had a large impact on their scores.

	CALMET-6	RAMS-CALMET	CALMET-1	CALMET-3
January	61 %	67 %	99 %	98 %
April	71 %	68 %	97 %	97 %
June	83 %	84 %	79 %	97 %

Table 4.2
Mean Relative Error (MRE) Scores for 24 Hour SO_2 Concentrations during each 5-day Period

4.3.4. Dispersion Summary

The hourly plots and the MRE scores indicate that the RAMS-CALMET model performed better than CALMET-1 and CALMET-3. RAMS-CALMET tended to overpredict concentrations at the higher elevation stations of Jail and CBC and underpredict levels in the bowl at Plaza. However, the CALPUFF model appears to naturally over-predict concentrations when very light wind conditions exist, as indicated by the CALMET-6 model during the June period.

There are two possible reasons for RAMS-CALMET underpredicting concentrations in the bowl; the inability of the RAMS model to correctly capture the vertical temperature profile for these cases and the tendency for this model to miss some of the easterly component of the flow as a northern wind is directed into town by the valley wall near the Prince George Pulp station. To determine the effect that the RAMS sounding had on dispersion estimates, a test run was initiated for the January period with the RAMS-CALMET model where the actual soundings at ZXS were used for the upper air data needed by CALMET, instead of the RAMS generated profiles. The new fields generated were then used for a CALPUFF run. The results of this test produced 24 hour SO_2 concentrations at Plaza on January 30 and 31 that were over 10 $\frac{\mu g}{m^3}$ (or about 50 %) higher than that predicted by the model initially (these figures are not included here). The concentrations at the other stations did not significantly change. This test was again performed for the April period, which resulted in a similar increase in the RAMS-CALMET concentrations of about 50 % for the Plaza values on April 17 and 18. As before, concentrations at the other (two) stations were not affected. These outcomes present clear evidence that the weaker stability regime modelled by RAMS was a major cause of the RAMS-CALMET model underpredicting concentrations in the bowl area. The CALMET-3 model, and more notably the CALMET-1 model, on occasion completely missed higher SO_2 concentrations. The cause is almost certainly because of their meteorological models failing to capture the dominant north-south valley flow during these intervals.

5. Discussion and Conclusions

5.1. Discussion

The analysis conducted in this study indicates that the use of the RAMS fields with CALMET produced meteorological fields that were as good or better than those from CALMET using one or three surface meteorological stations. Although the RMSVE values were high for RAMS-CALMET, it was able to model the wind direction in the valley reasonably well, especially at night. CALPUFF dispersion estimates made using the RAMS fields, although having errors, were more representative of observations than those made with the one and three station CALMET fields. CALPUFF estimates made with 6-station CALMET fields clearly were better than those made with the CALMET 1 and 3-station models, but only marginally better than those made with the RAMS-CALMET fields.

5.1.1. Meteorological Fields

There was evidence that RAMS accounted for much of the influence of topographical heights on the regional winds. There were strong indications of channelling in the modelled winds at Northwood and Prince George Pulp during each five day period. RAMS was able to develop the drainage type flow in the valley in each test case, even when modelled winds at higher elevations were incorrect. The CALMET model, using station data, had trouble developing these katabatic winds, at times even when the winds at Northwood were used as input. The choice of switching off CALMET’s problematic ‘kinematics’ algorithm may have influenced this in part, although this was a necessary step for the modelling exercise. It is likely that CALMET-3 would have performed better at both its wind and SO_2 predictions if it had used the Plaza station winds as input instead of those from University. It appears from this study that CALMET needs the data from at least two meteorological stations within the valley to accurately model surface winds in the Prince George airshed.

Surface wind speed predictions from RAMS were consistently too low, especially in the valley. This led to error in the wind fields produced by RAMS-CALMET. Other recent studies do not show a similar modelling effect. Lyons *et al* (1995), using RAMS initialized by both the large scale NCEP datasets and available regional observations for dispersion modelling near Lake Michigan found the opposite - that predicted surface winds were higher in magnitude than observations showed. Cox *et al* (1998) found this same general trend in all four prognostic models (including RAMS) they were analyzing. The low modelled wind speeds from RAMS may have been a result of using roughness lengths that were too high for portions of the Prince George domain. Roughness length is a parameter that quantifies the effect the landscape has on wind speeds near the surface (Stull, 1995). RAMS was set to internally calculate a roughness length for each grid cell in the domain using its standard datasets of topographical height and vegetation class at 30 arc-second intervals of latitude and longitude. The option of constructing a separate file containing a roughness length for each grid cell was not used. Exercising this option for the fine model grid probably would result in roughness lengths more suitable for the grid cells within the valley portion of the domain. The use of a local meteorological station in addition to the NCEP fields in the initialization of RAMS likely would have improved the accuracy of its surface wind speed values. The RAMS version 4.3 does not have the capability of being initialized by station data alone, although earlier versions had this option. CALMET-1 and CALMET-3 largely avoided any problem with surface wind speeds since their wind fields are a result of interpolation or extrapolation (with modifications) from observed wind speeds. However, this procedure had trouble modelling wind direction when observed wind speeds were very low; a problem RAMS-CALMET did not exhibit.

The use of the NCEP fields as the only meteorological input to the RAMS model led to two notable features in the modelled fields. The first was that some of the boundary layer characteristics were inaccurate during evenings of high stability. In particular, RAMS missed the proper strength of the inversion conditions that developed during the January and April periods. Other modelling studies have shown similar problems accurately representing boundary layer features when using NCEP fields alone (e.g. Guan *et al*, 1997). Lyons *et al* (1995), using similar vertical spacing to that used in this study suggested that RAMS may have been unable to resolve shallow surface-based inversions during their modelling exercise. The second notable modelled feature was that the veering of wind direction with height in the valley was inaccurate at times. This may be linked to the difficulty RAMS had with modelling wind speeds.

During 2 of the 3 test periods, RAMS did not capture the strength of overnight inversions. Because the NCEP initialization data does not have the resolution needed to articulate a shallow boundary layer, RAMS must develop this as it progresses through a run. This was a difficulty for the model. By not properly modelling the layer of colder air developing over the surface, boundary-layer pressure gradients and their effect on surface winds were under-represented. Pielke and Uliasz (1998) stressed the important role vegetation can have on the vertical structure of the Atmospheric Boundary Layer. RAMS determined the vegetation class for each grid cell from a 30 arc-second global dataset. Similarly to roughness lengths, vegetation class can be specified in a user-generated file and read by the model during initialization. Having the operator provide individual grid cell vegetation classes and roughness lengths for the innermost model grid might improve RAMS' ability to model a shallow boundary layer for the Prince George domain. These could be interpreted from an aerial photo of the region.

5.1.2. SO_2 Concentrations

During several intervals RAMS-CALMET modelled SO_2 concentrations that were more similar in pattern to those predicted by CALMET-6 than either CALMET-1 or CALMET-3. However, CALMET-6 was not the most accurate model in each of the 5-day periods. This indicates that the three 5 day intervals used for comparisons may not have been long enough to constitute a reasonable test. The problem with RAMS-CALMET under-predicting wind speeds in the valley likely was a cause of this model predicting alarmingly high 1-hour concentrations on a few occassions. But the fact that the CALMET-3 and CALMET-6 models also displayed this behaviour indicates that the CALPUFF dispersion algorithm, when applied to near calm conditions, generally over-predicts SO_2 concentrations.

The RAMS-CALMET dispersion model was relatively successful when compared to CALMET-1 and CALMET-3. There were recurring troubles however. The problem with RAMS' temperature profiles within 300 m of the surface caused CALPUFF to underpredict SO_2 concentrations in the bowl during the January and April periods. Since fumigation is commonly responsible for higher concentrations developing in the valley, incorrectly modelling the strength of surface inversion conditions had a negative effect on CALPUFF modelling this type of circulation. RAMS was not able to accurately model the north-easterly winds at Prince George Pulp that commonly occur as a northerly valley flow develops. With this circulation the downtown core is directly downstream of the major SO_2 sources. This is probably a secondary cause of RAMS-CALMET underpredicting concentrations in the bowl during the January and April cases. By missing some of the influence the valley configuration has on wind direction, this model overpredicted SO_2 levels at Jail and CBC.

Mean Relative Error scores indicated that the RAMS-CALMET model was relatively successful at predicting 24-hour SO_2 concentrations. The fact that the error associated with CALMET-1 was largely due to underpredicting these levels is a cause for concern, since dispersion models are commonly expected to indicate worst-case scenarios (e.g. Zannetti, 1981). This may constitute a serious flaw of the CALMET-1 model that is not represented by its MRE score. The MRE scores also showed that CALMET-3 was not significantly more accurate than CALMET-1.

5.2. Conclusion

The results determined here show that RAMS is able to model episodic meteorological conditions in the Prince George domain without the use of local meteorological data. The focus of this work was to consider the feasibility of using mesoscale model fields in lieu of local observations in performing a dispersion modelling exercise. Although mesoscale models have been used in dispersion studies in many different areas, most of these studies have been on a regional scale looking at areas of interest much larger than the one here. This exercise instead looked at conditions that a regulatory dispersion model would normally analyse. Comparisons have been made with recent mesoscale/dispersion model combinations, with some commonalities identified. Further modelling needs to be done at the scale of this work before strong conclusions can be made.

This study supports the idea that a mesoscale model such as RAMS can be a useful tool in regulatory dispersion modelling, especially in areas where there is a scarcity of meteorological observations. The practitioner however must first become very familiar with the mesocale model, which represents a greater investment of time than with a dispersion model. A drawback to using this approach is that the computer requirements are much more significant than with a standard regulatory model. However, with the rapid advance of computer processing power, this problem is likely to diminish in the future.

6. Recommendations

It is probable that the RAMS modelling of boundary layer wind and temperature can be improved if several features are considered. There are many parameters to set in model initialization, but those in particular that influence surface layer winds need to be assessed. Allowing the model to determine roughness and vegetation class from a global dataset may not constitute a reasonable representation of the urban/suburban mix for an area such as the one in this study. In addition, the problem modelling a shallow boundary layer indicates a need to either include meteorological station data with the NCEP fields, or to gain a clear understanding of what limitations result from the use of the NCEP fields alone. Longer study times also need to be considered, especially if the modelled fields are to be used with a dispersion model.

It would be useful to determine if the problems that RAMS had in modelling boundary layer characteristics are consistent with other mesoscale models. The application of other models such as MC2 (Mesoscale Community 2) or MM5 (Mesoscale Model 5) to the same domain and time periods could provide additional insight to the potential limitations of using mesoscale model fields in regulatory modelling.

Specifically, suggestions include:

- Application of this method to a greater number of cases to strengthen the conclusions made in this research.
- A RAMS sensitivity test, using the Prince George domain, of boundary layer features (especially winds) with surface roughness and vegetation classification. This would include assigning individual values of these parameters to each grid cell.
- Application of MC2 or MM5 to the Prince George domain with the intent of comparing output fields with RAMS.
- Application of this method to another area possessing both complex terrain and

observation sites that can be used to test model fields. Results could be compared to this study to look for commonalities.

• A study of the relationship between the size of the innermost domain of a mesoscale model and the representativeness of modelled features to local observations in areas of complex terrain.

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APPENDIX A

A.1. Modelling Domains and Features

Note: To facilitate comparisons between the three modelling periods, figures are grouped together by type and not specifically in the order referenced.

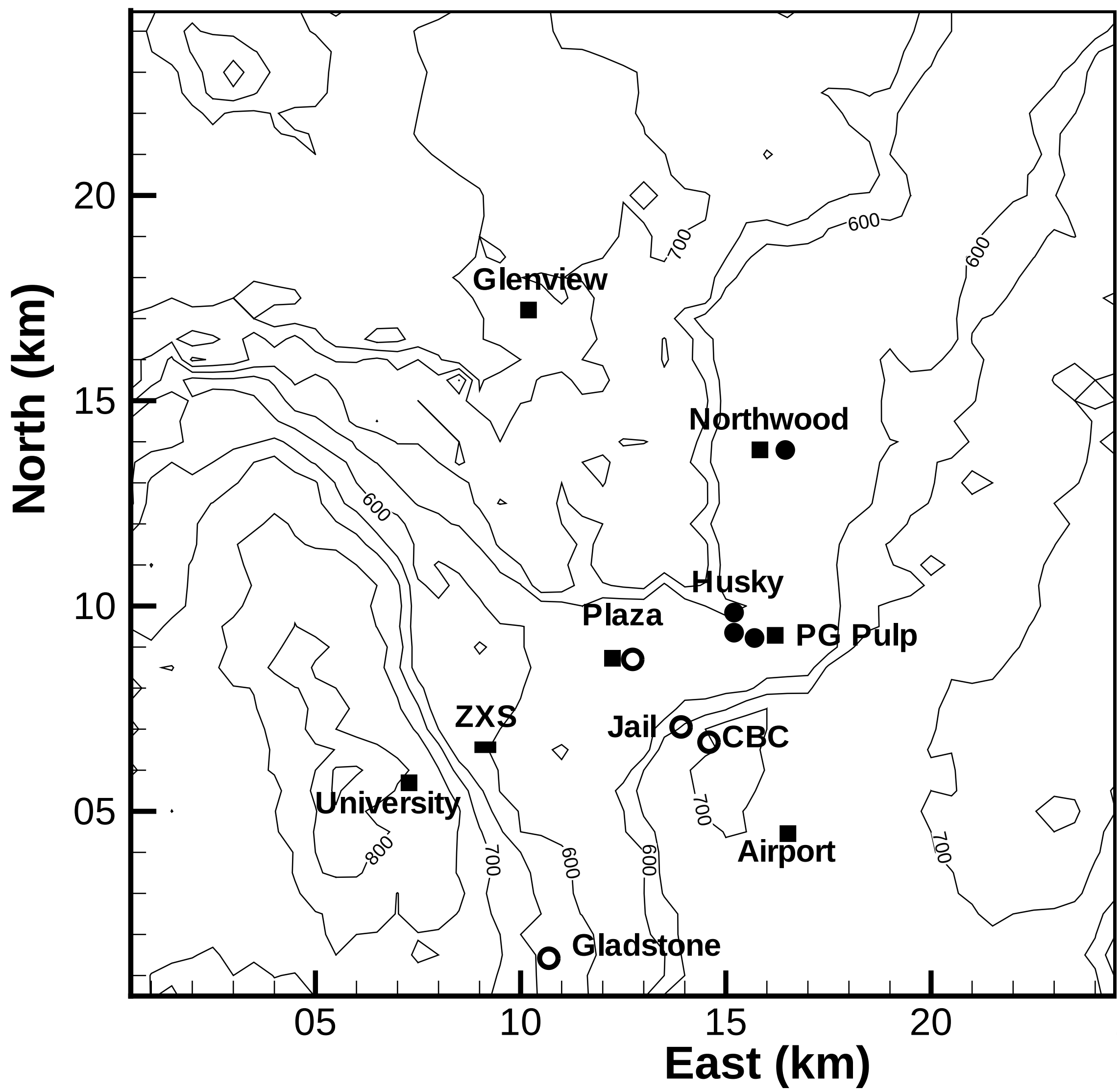


Figure A.1. **Prince George domain** for CALMET and CALPUFF modelling. Squares represent the surface met. stations, rectangle the upper air station, open circles the SO_2 monitoring stations and closed circles the significant SO_2 sources. Contours are terrain elevation in meters above sea level

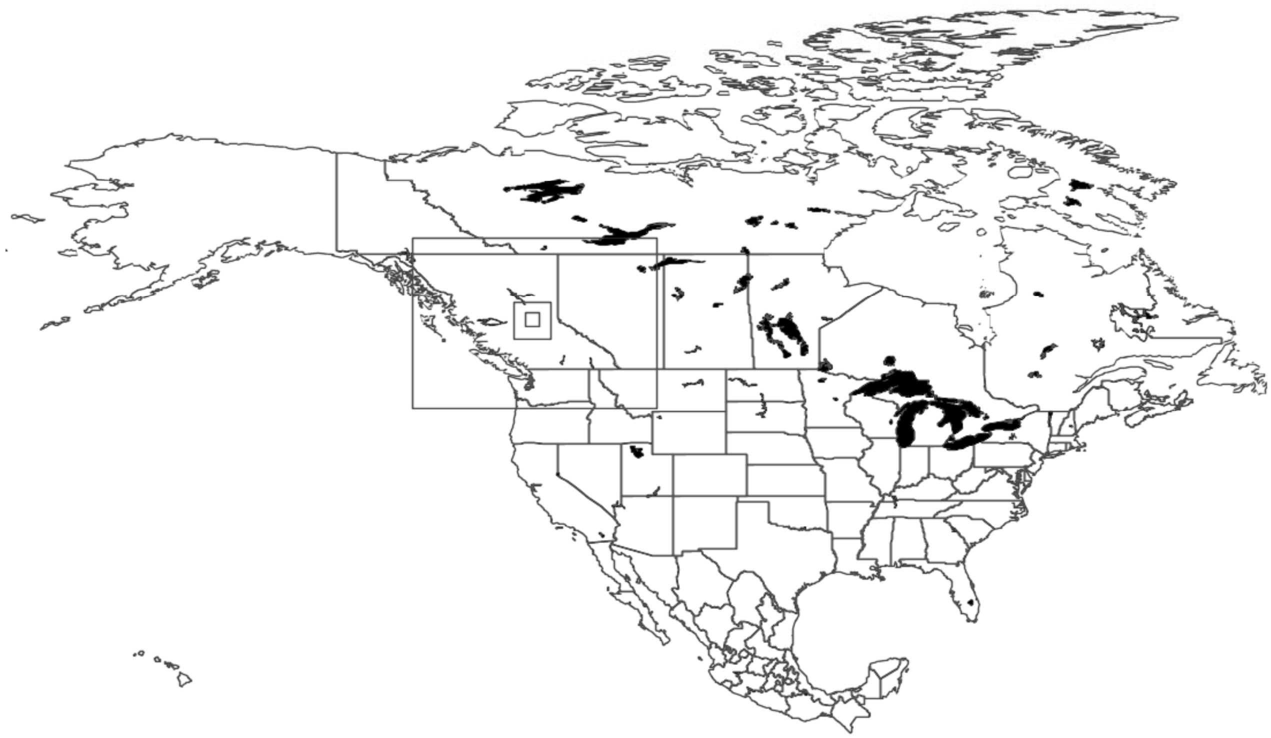


Figure A.2. Nested grids for RAMS runs. Each grid centered on Prince George British Columbia.

A.2. Regional Climatology for the Three Study Periods

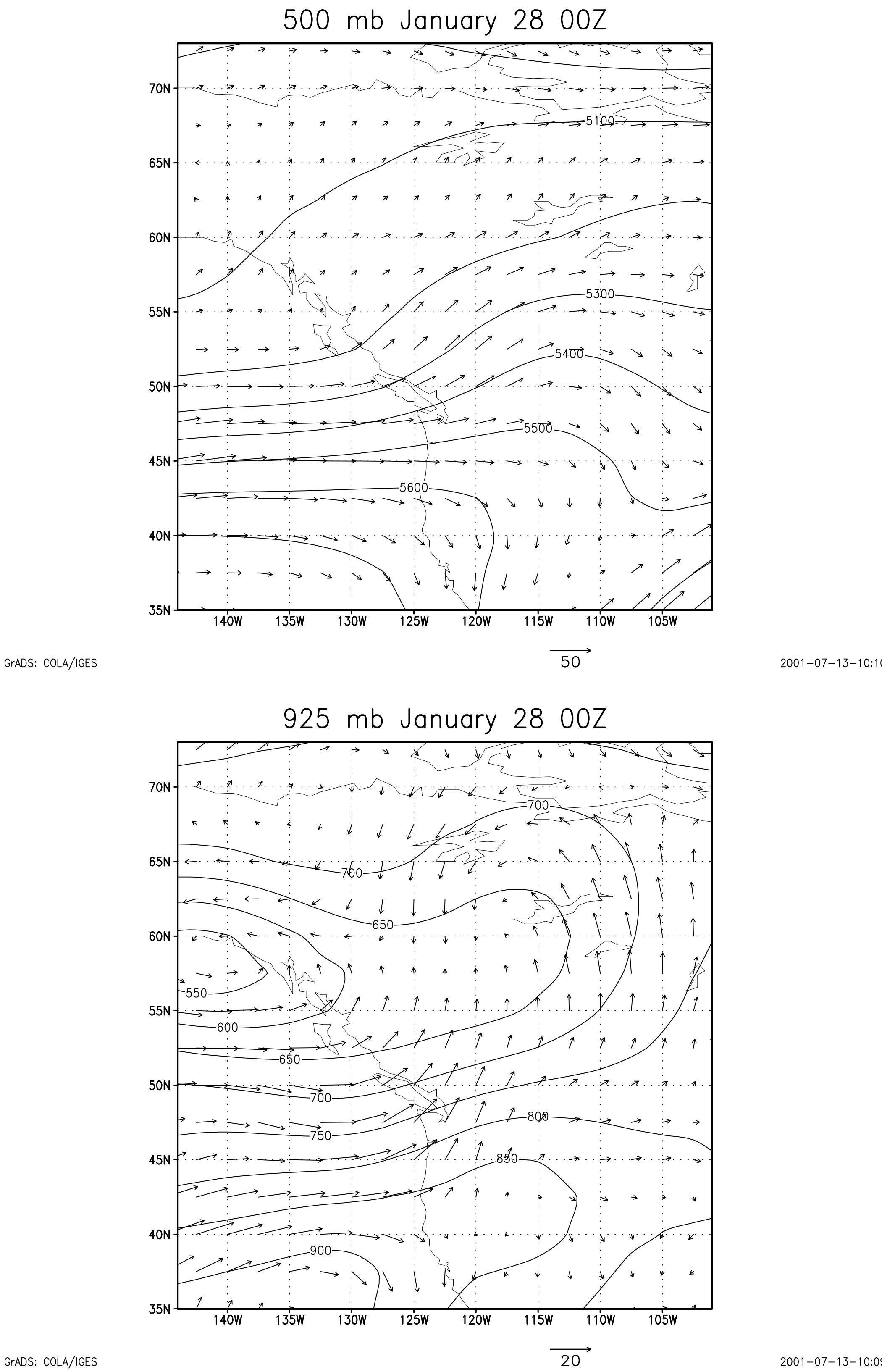
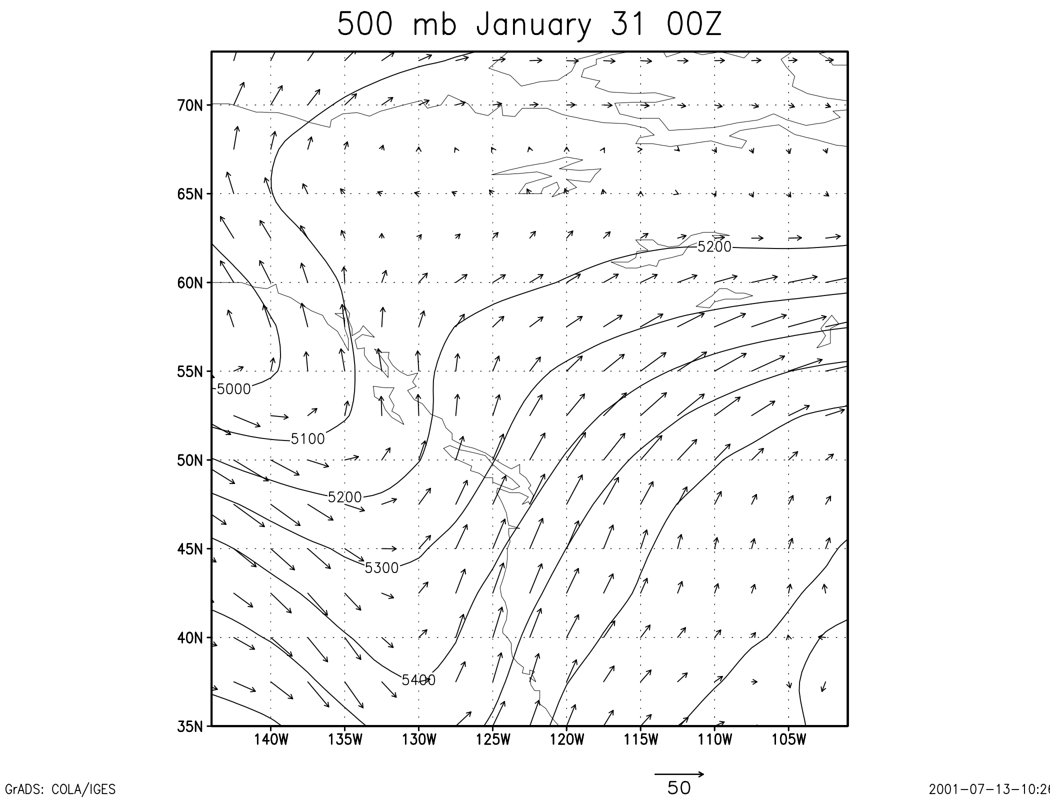


Figure A.3. 925 and 500 hPa height contours, showing vector winds. Beginning of January period. Each chart centered on Prince George (54N, 122W).



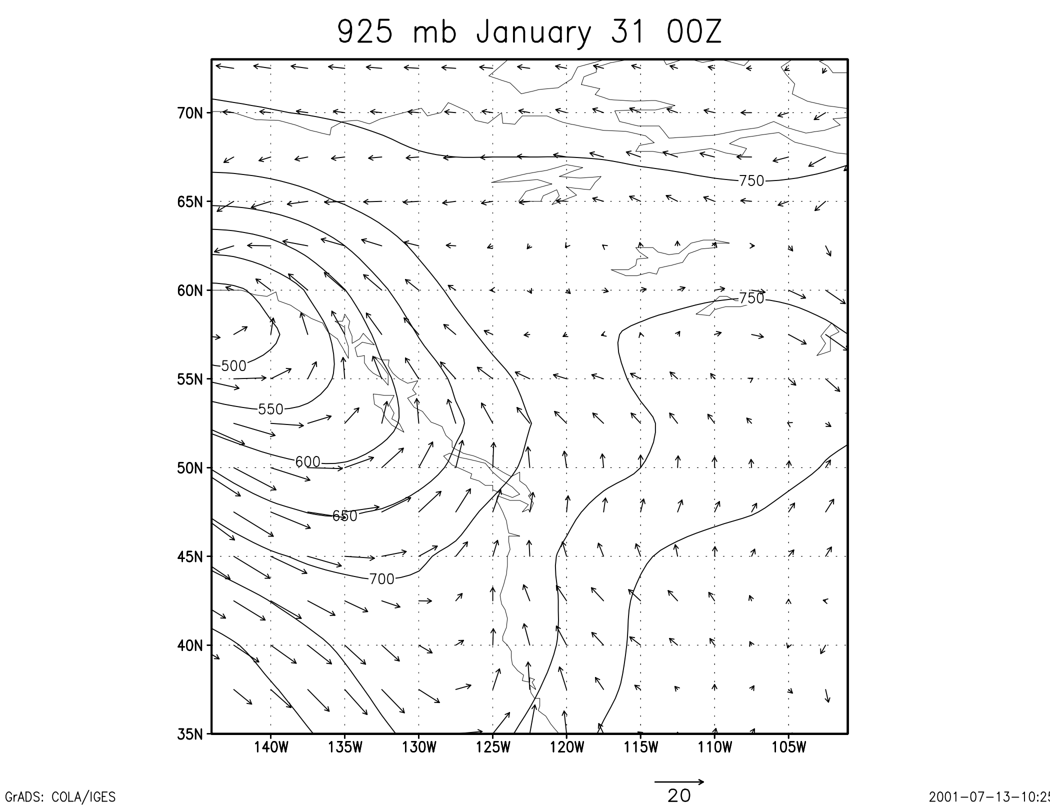
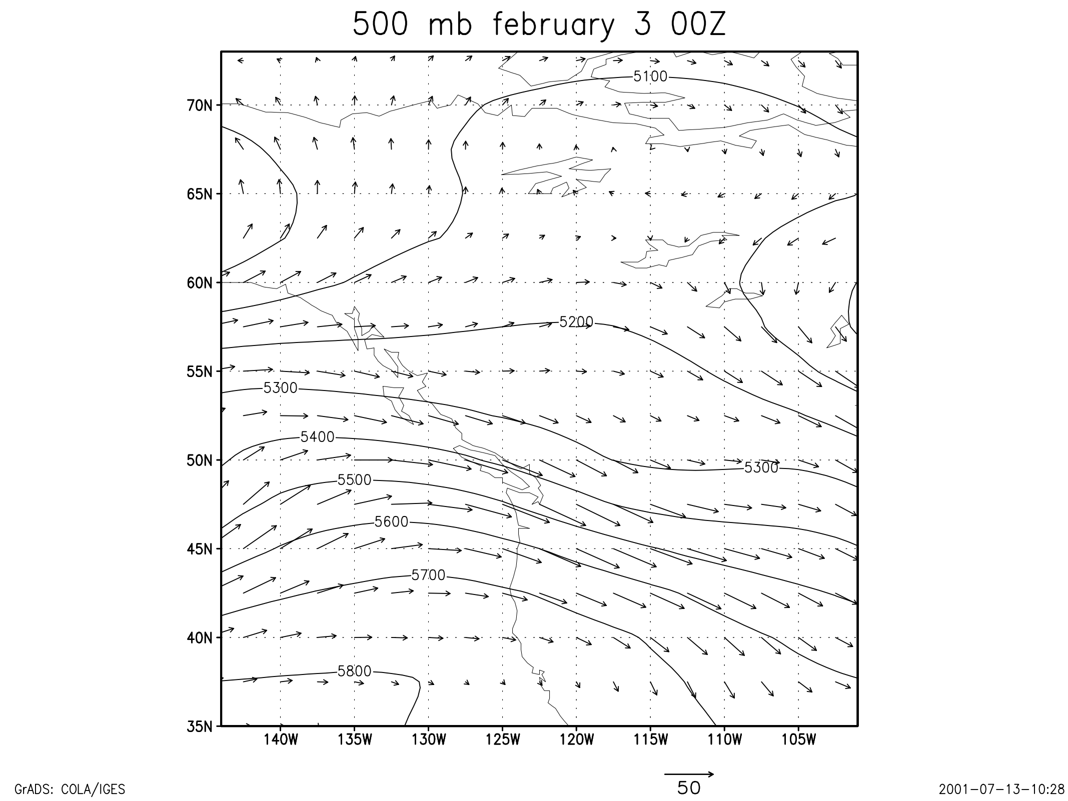


Figure A.4. 925 and 500 hPa height contours, showing vector winds. Middle of January period. Each chart centered on Prince George (54N, 122W).



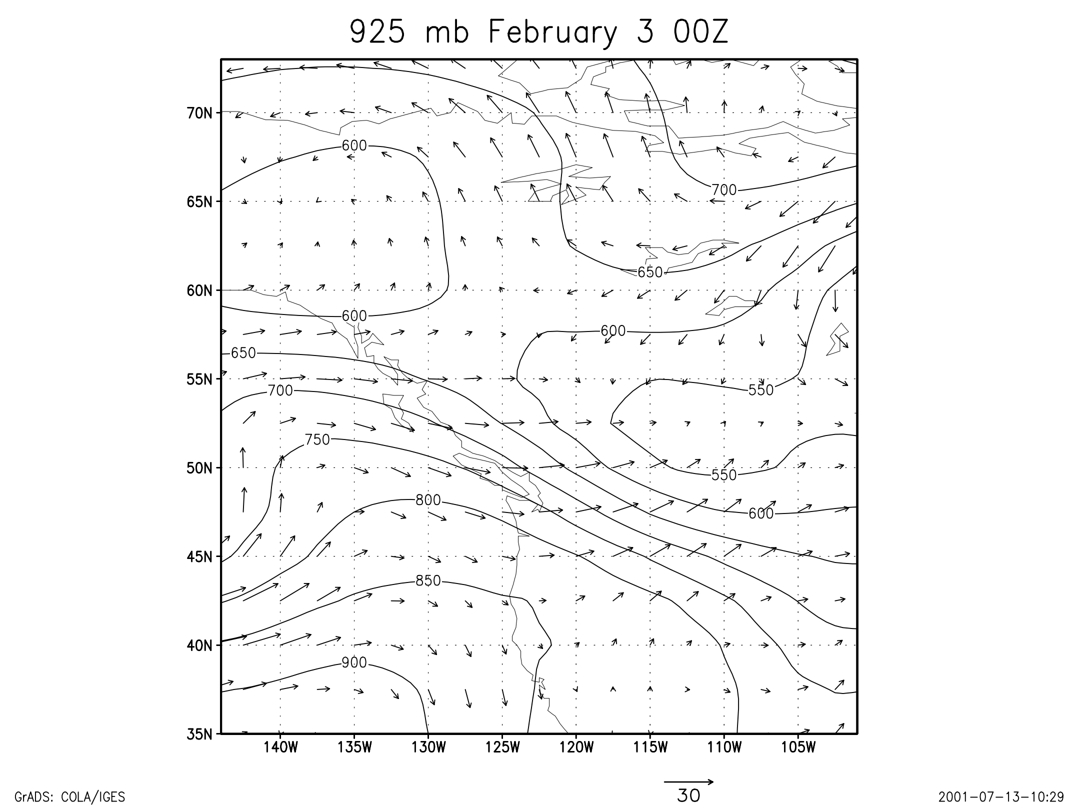


Figure A.5. 925 and 500 hPa height contours, showing vector winds. End of January period. Each chart centered on Prince George (54N, 122W).

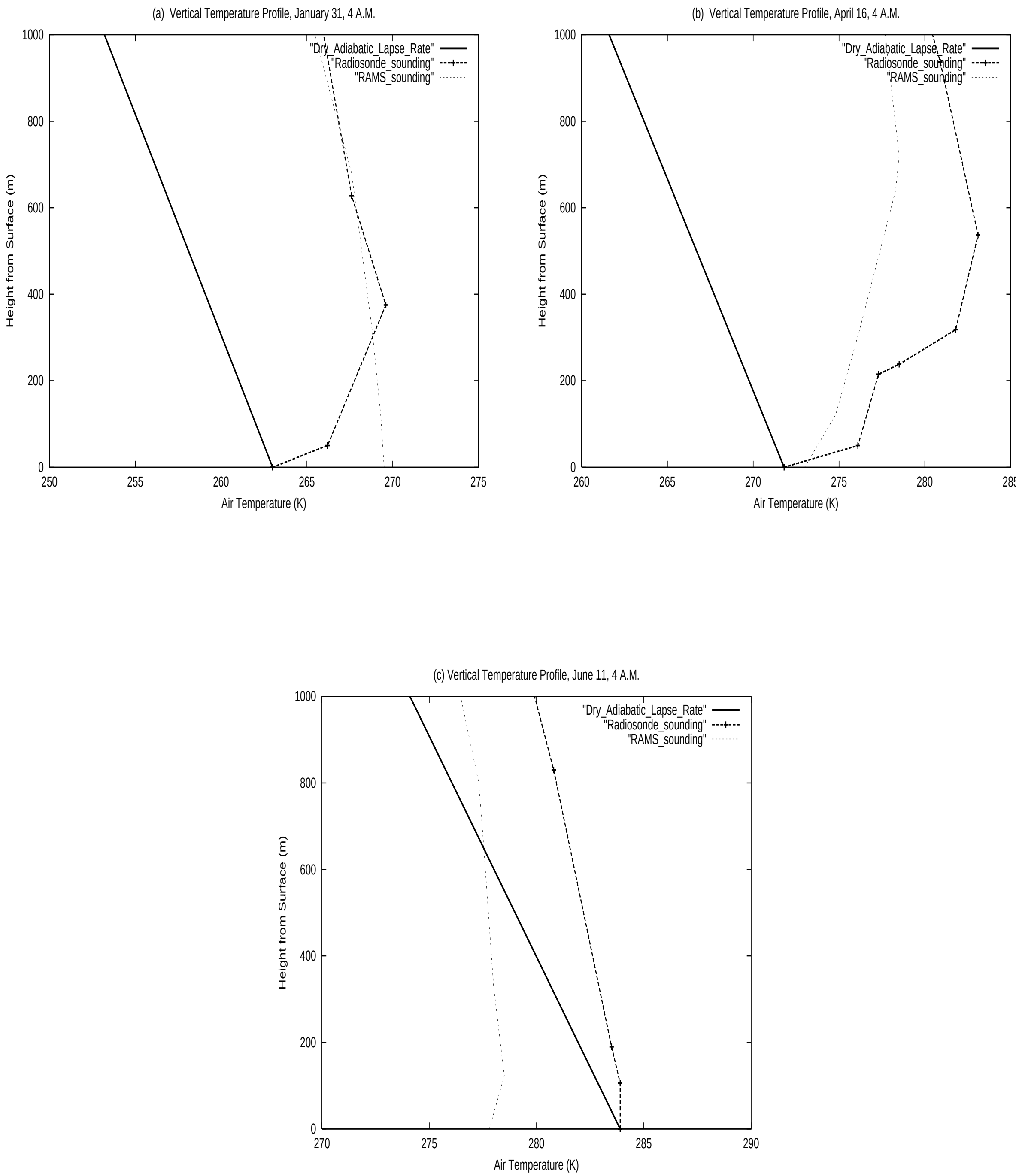
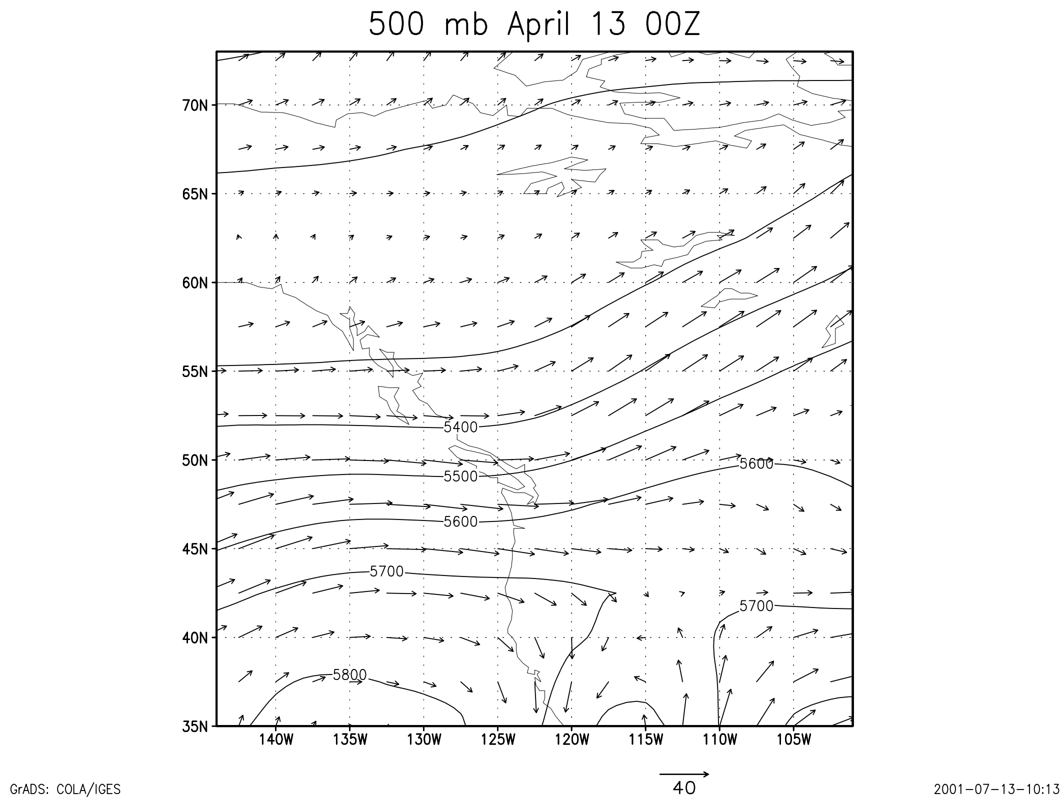


Figure A.6. Observed and Modelled Boundary Layer Temperature Soundings



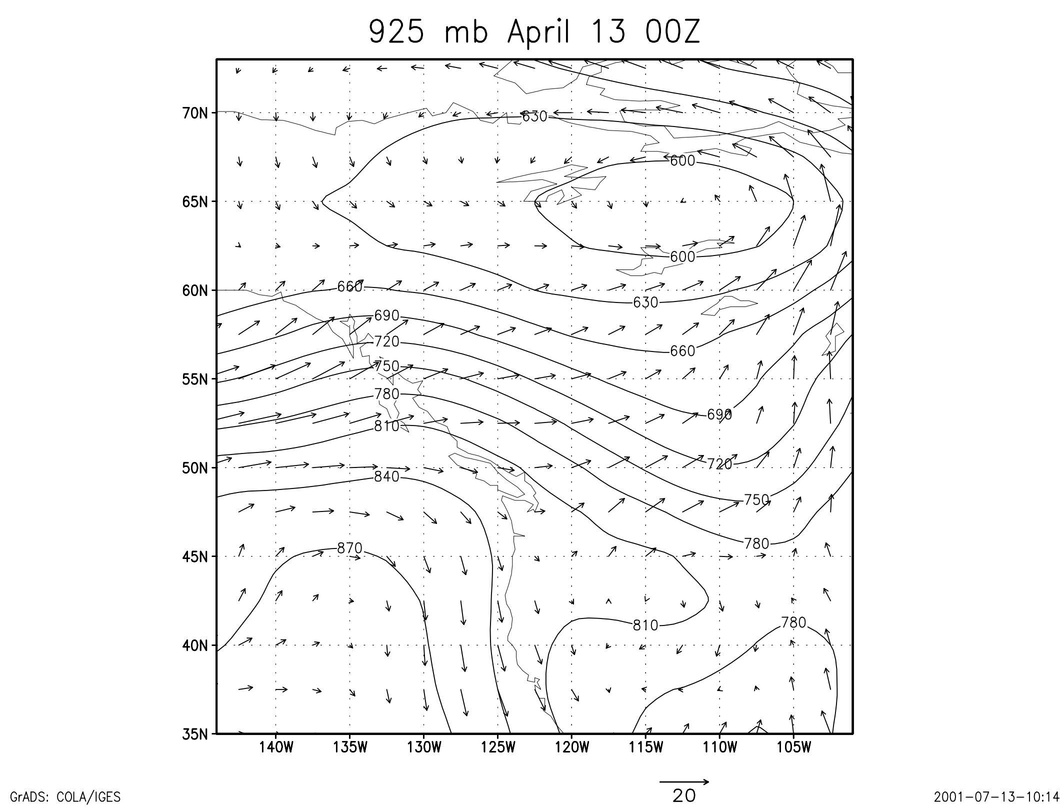
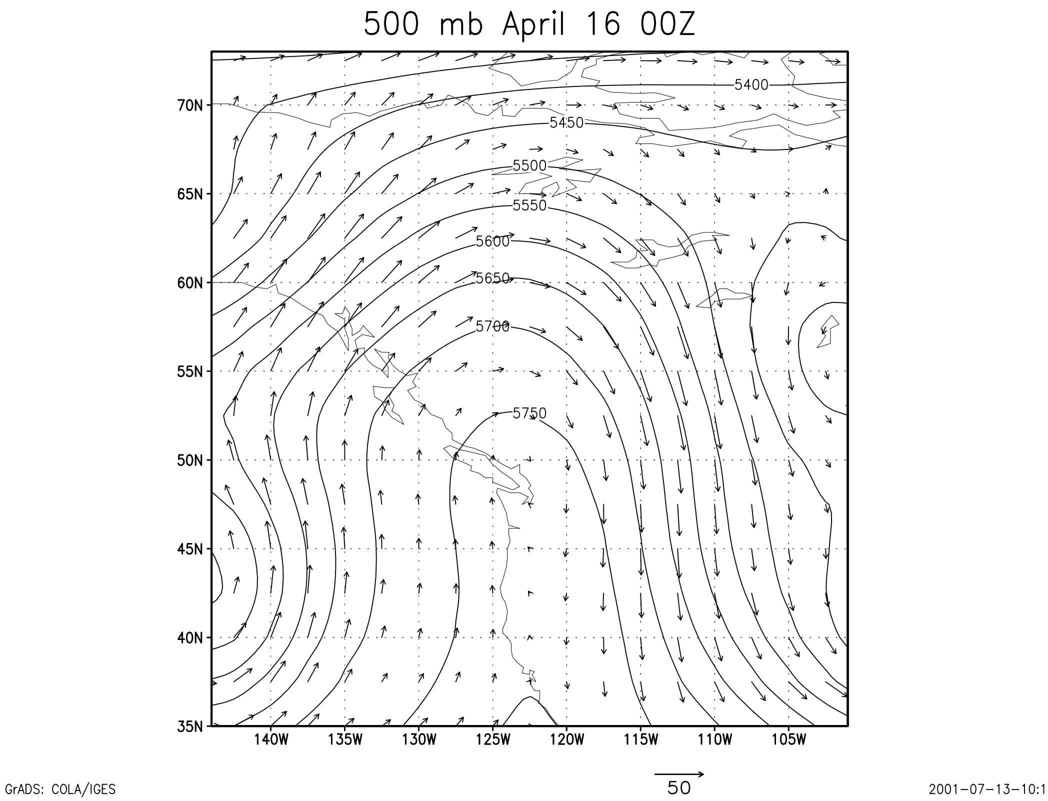


Figure A.7. 925 and 500 hPa height contours, showing vector winds. Beginning of April period. Each chart centered on Prince George (54N, 122W).



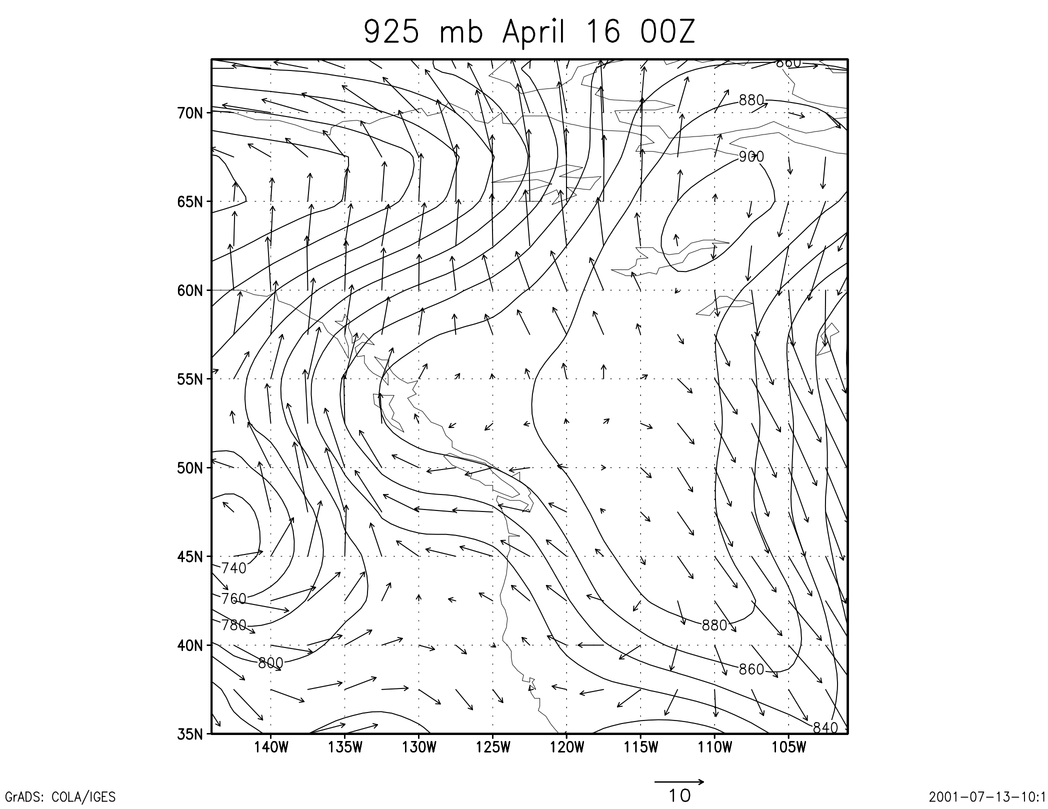
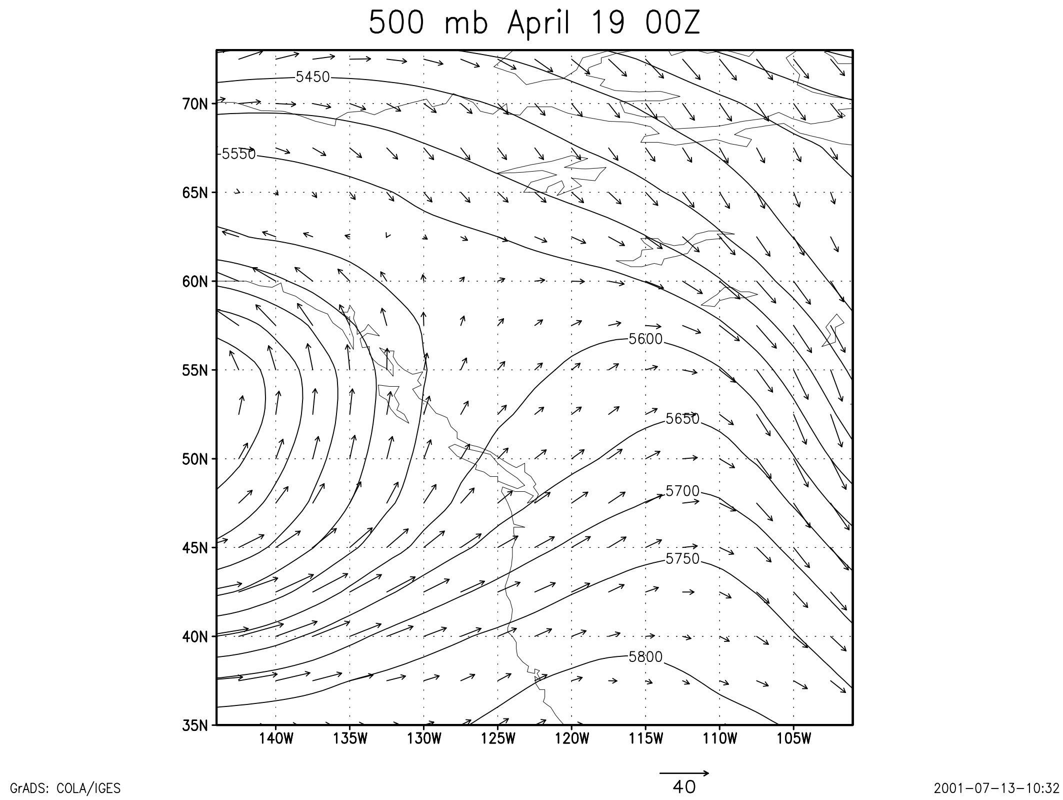


Figure A.8. 925 and 500 hPa height contours, showing vector winds. Middle of April period. Each chart centered on Prince George (54N, 122W).



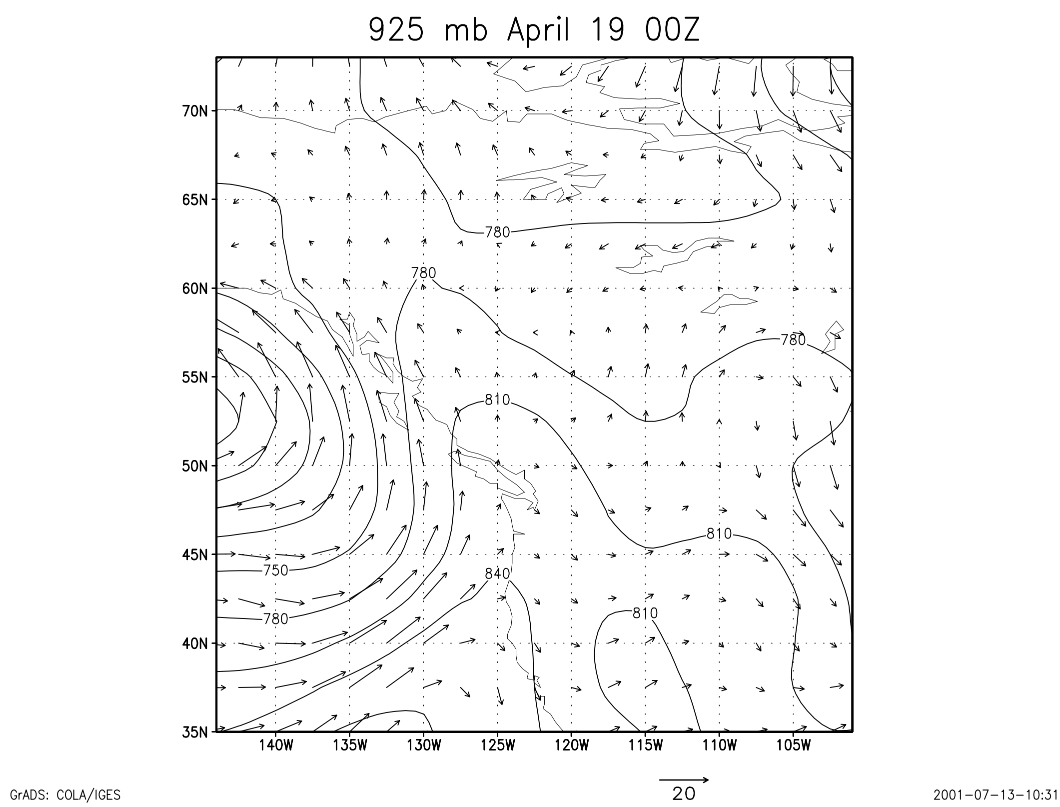


Figure A.9. 925 and 500 hPa height contours, showing vector winds. End of April period. Each chart centered on Prince George (54N, 122W).

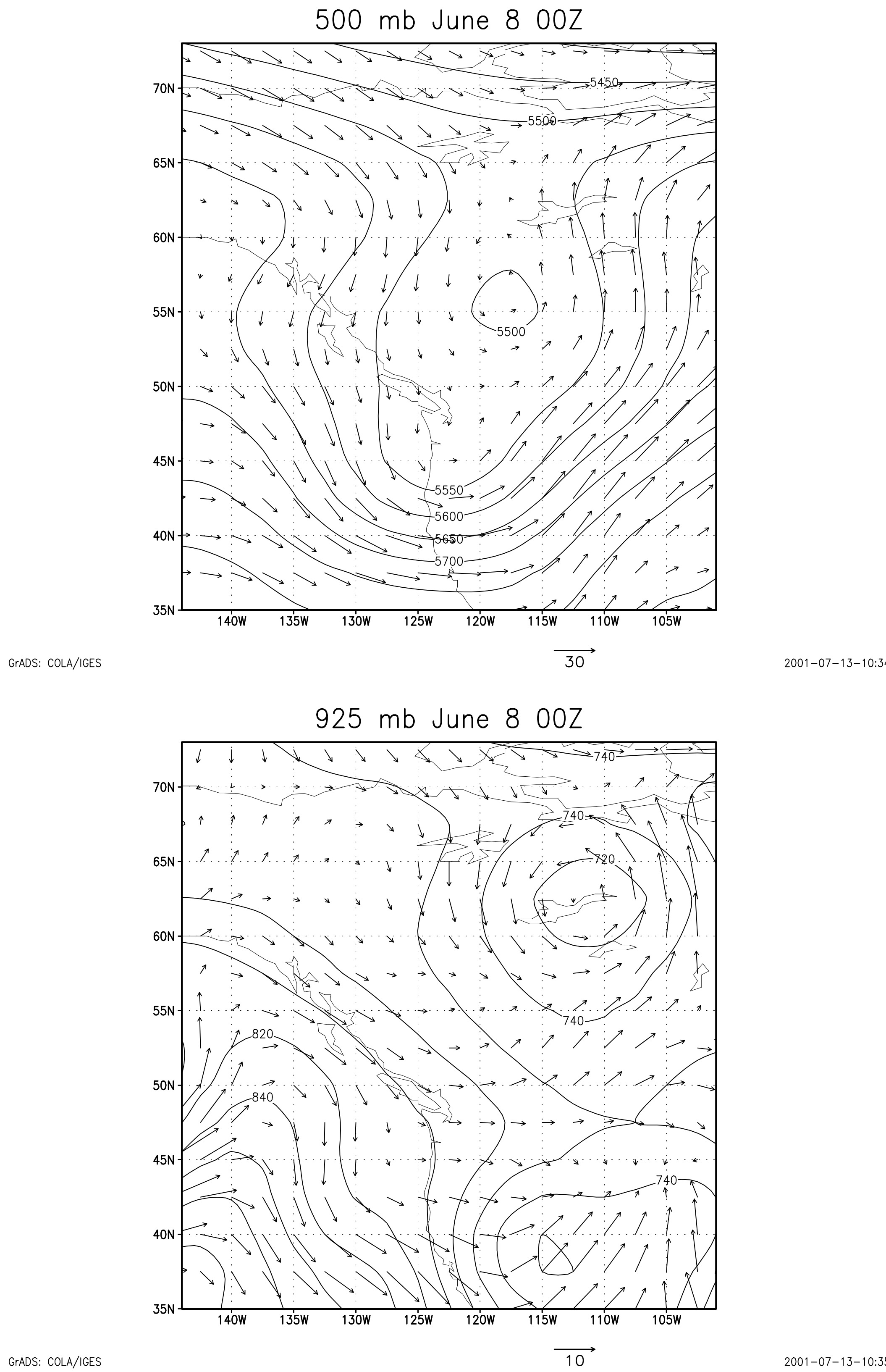
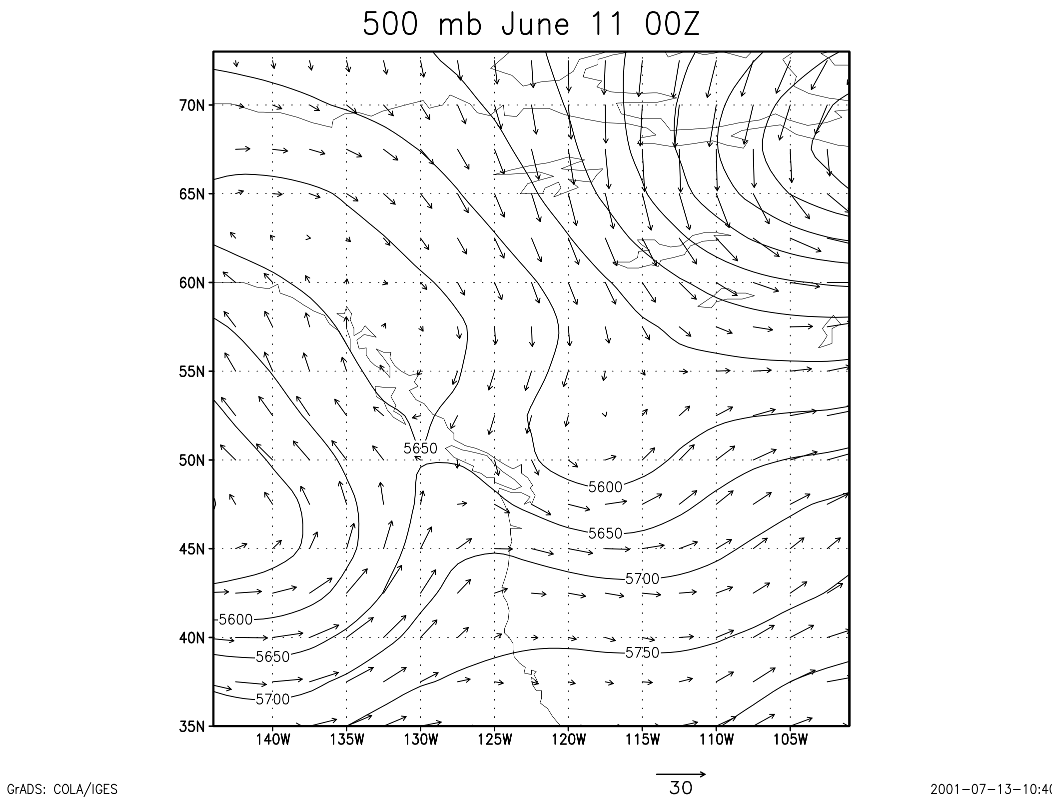


Figure A.10. 925 and 500 hPa height contours, showing vector winds. Beginning of June period. Each chart centered on Prince George (54N, 122W).



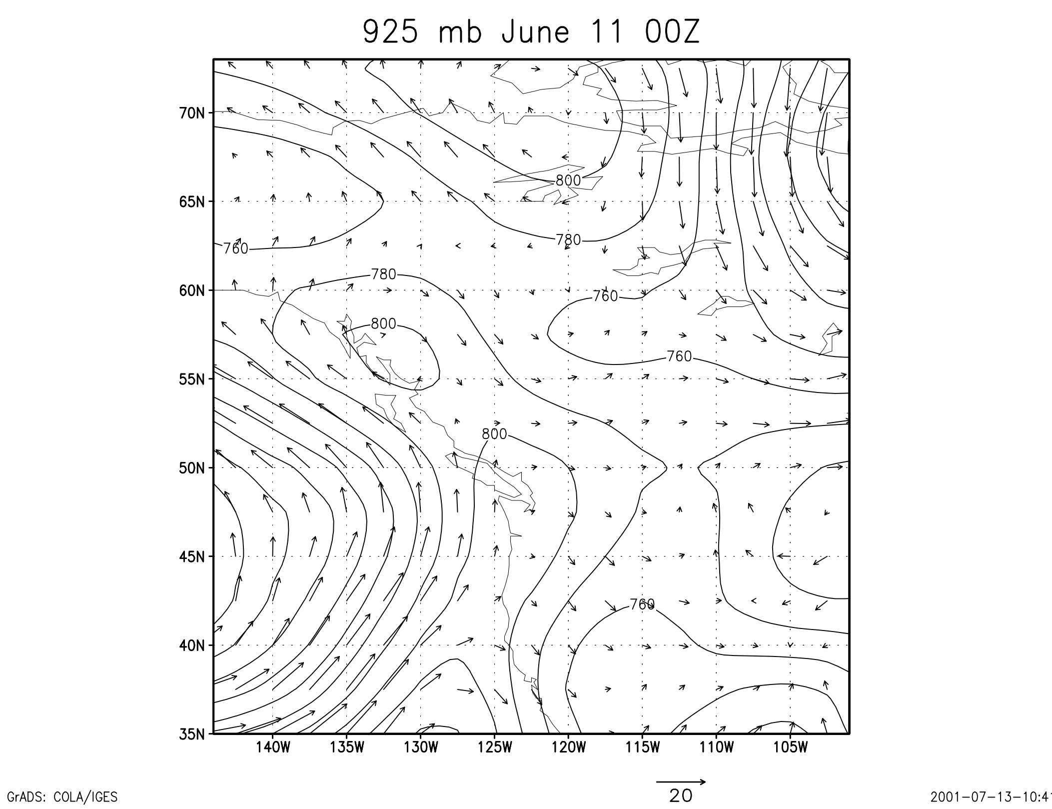
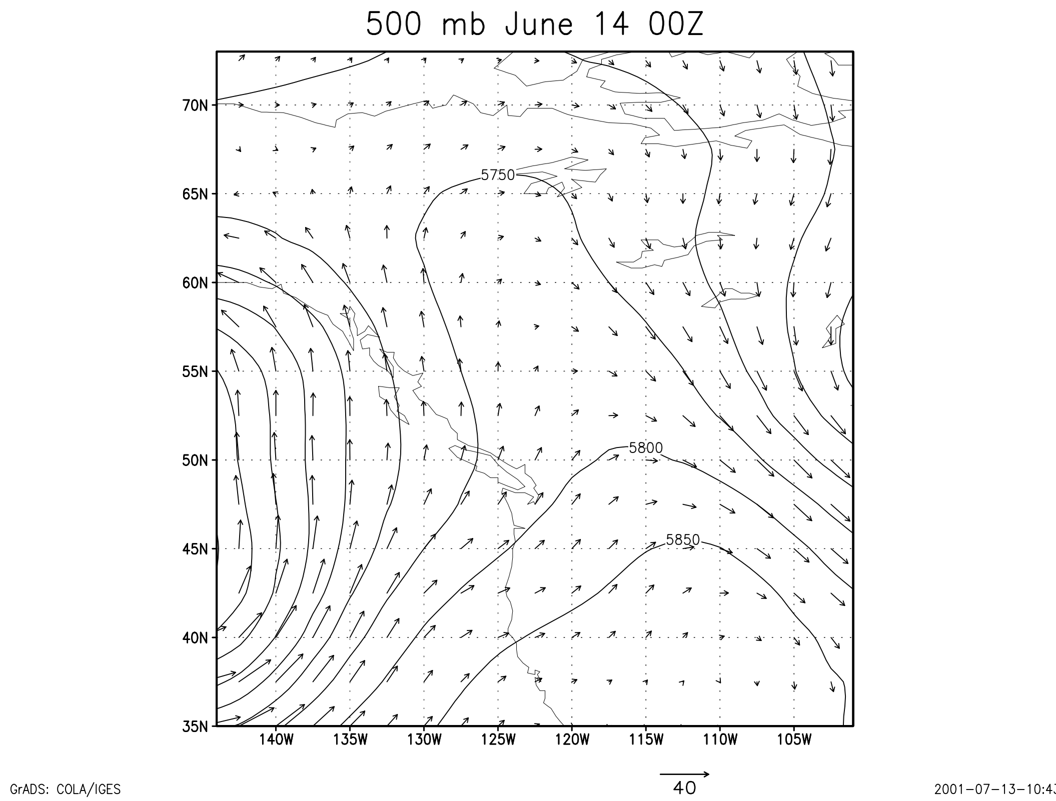


Figure A.11. 925 and 500 hPa height contours, showing vector winds. Middle of June period. Each chart centered on Prince George (54N, 122W).



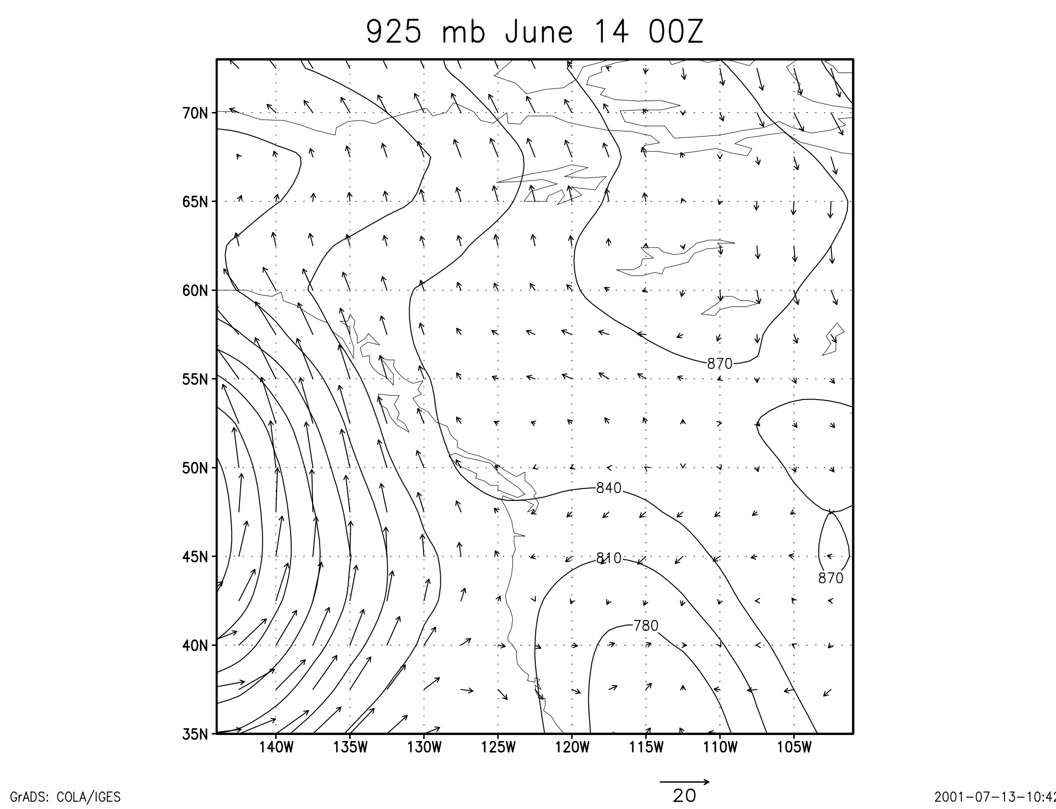


Figure A.12. 925 and 500 hPa height contours, showing vector winds. End of June period. Each chart centered on Prince George (54N, 122W).

A.3. Root Mean Square Vector Error

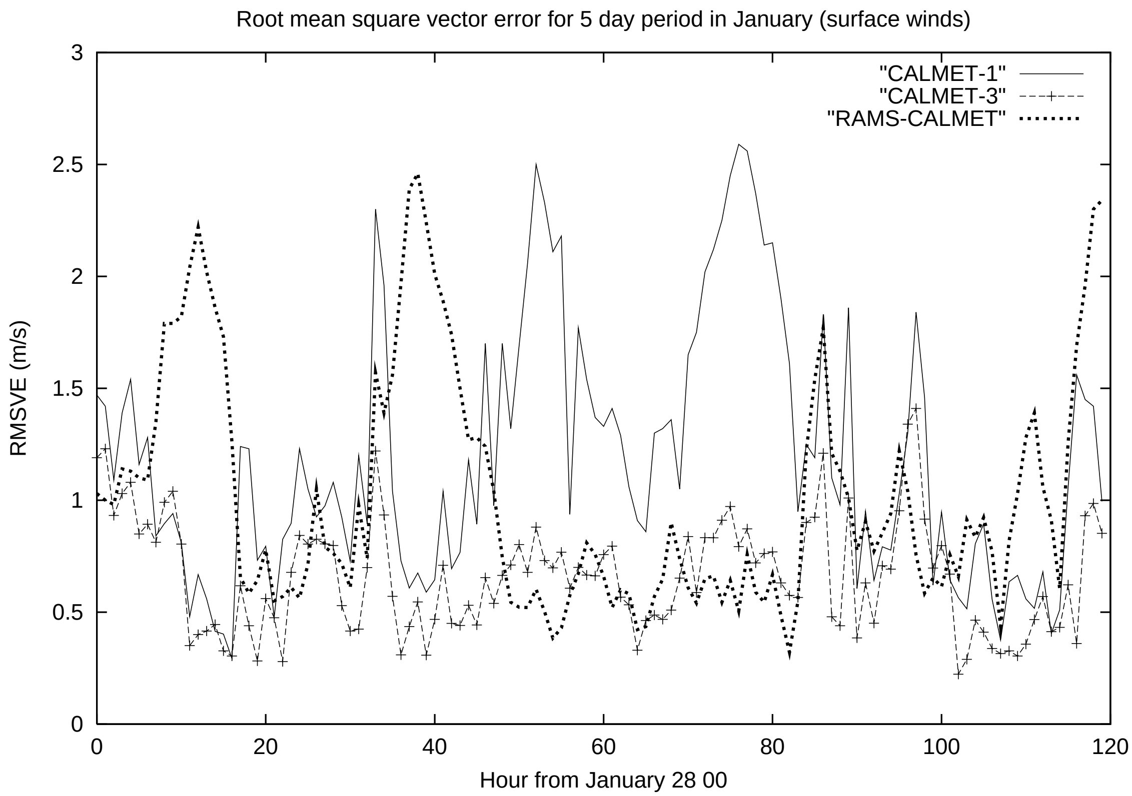


Figure A.13. Root Mean Square Vector Error: modelled winds from observations at five surface stations, January 28 to February 1.

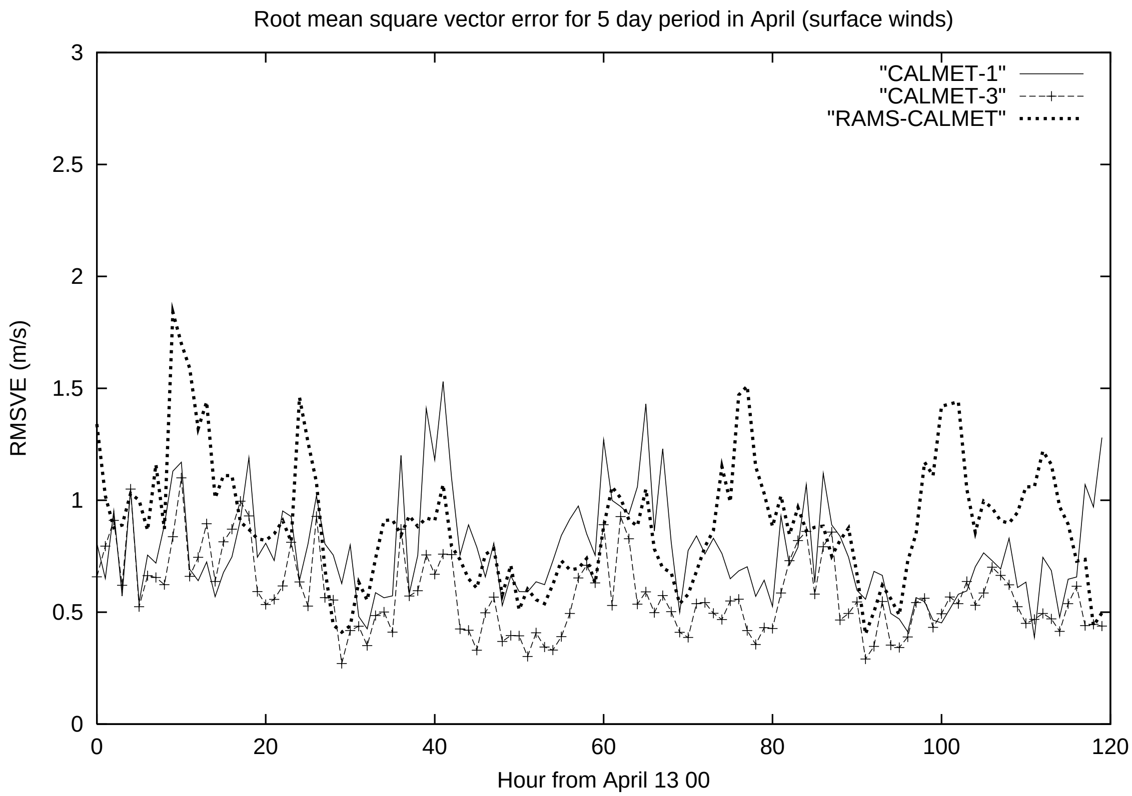


Figure A.14. Root Mean Square Vector Error: modelled winds from observations at five surface stations, April 13 to 17.

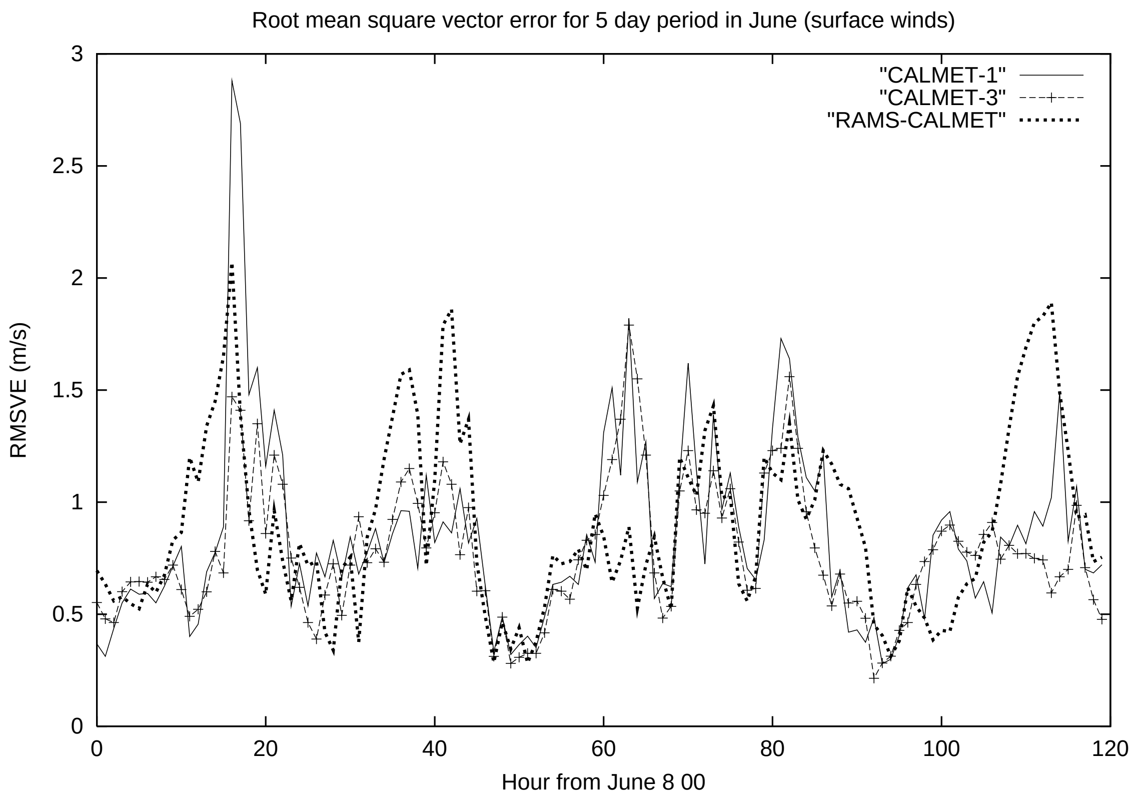


Figure A.15. Root Mean Square Vector Error: modelled winds from observations at five surface stations, June 8 to 12.

A.4. Windrose Plots

Note: Although the same wind speed categories are used for each plot, the frequency rings are relative to the most frequent wind direction. Frequency percentiles, indicated on each ring, are not the same for every plot.

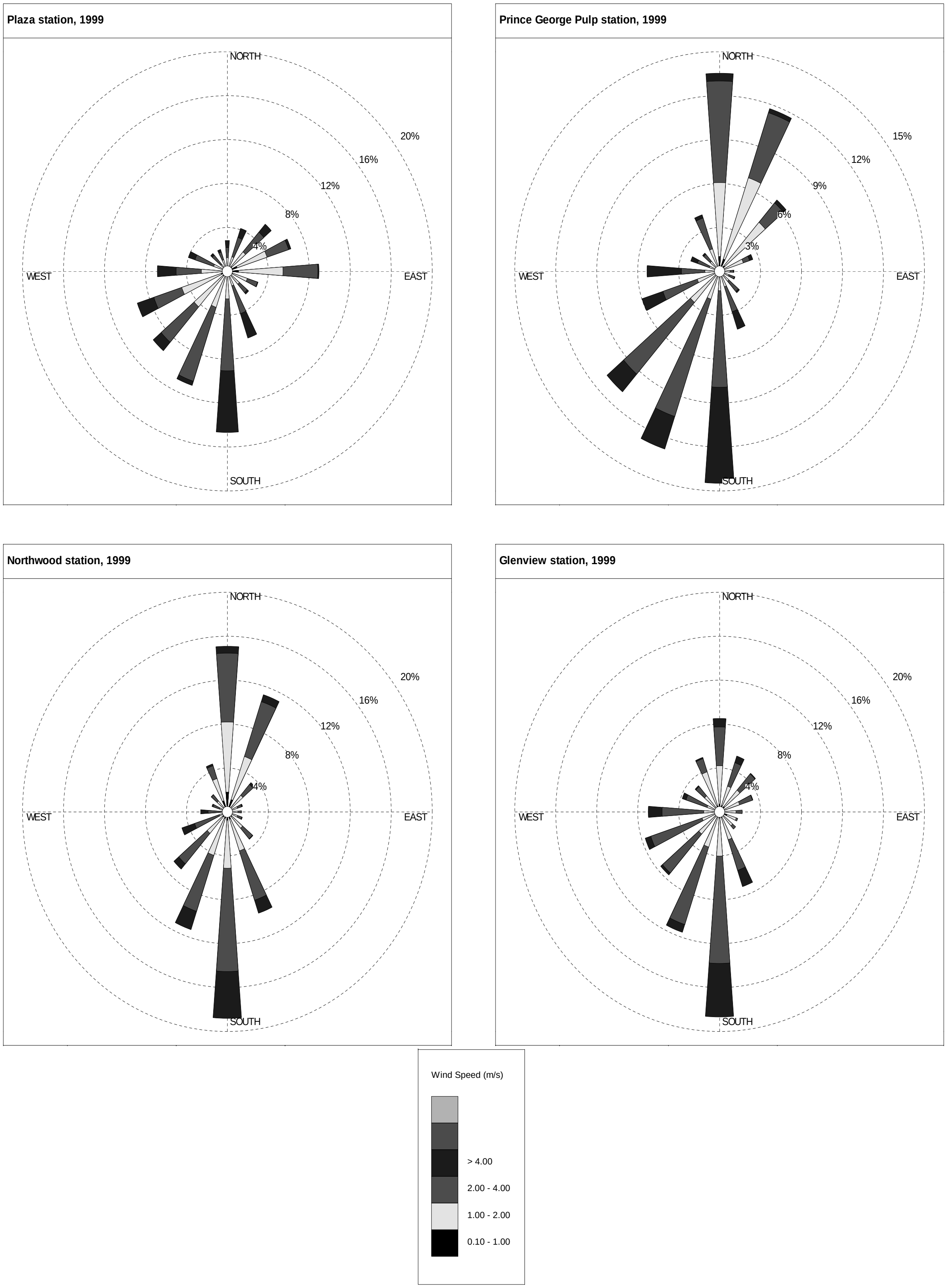


Figure A.16. Windrose diagrams showing wind direction for the year of 1999. Plaza, P.G. Pulp, Northwood and Glenview stations are shown.

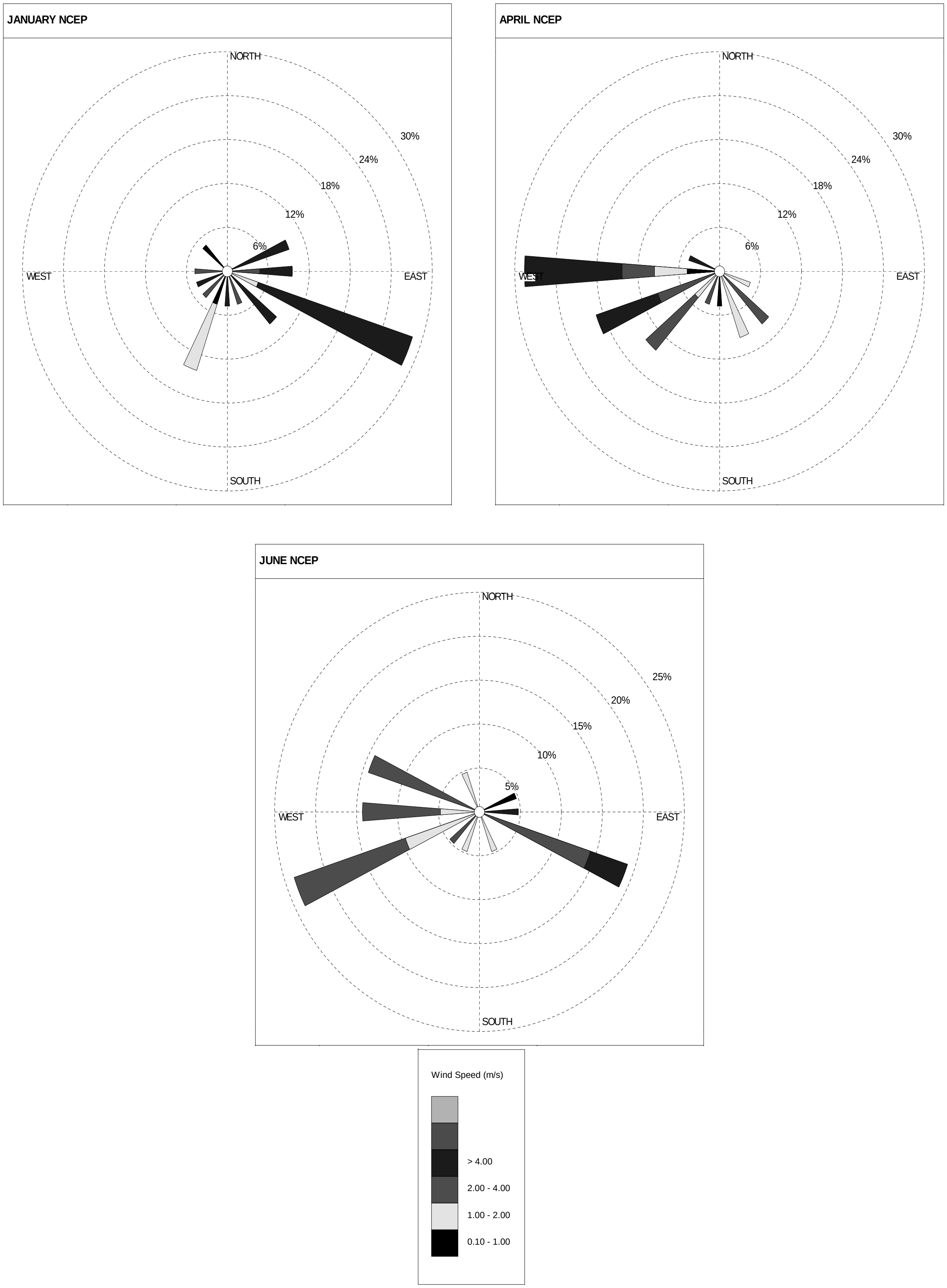


Figure A.17. Windrose diagrams showing the surface winds for the six-hourly NCEP reanalysis fields for the region surrounding Prince George. The periods January 28 to February 1, April 14 to 18, and June 8 to 12 are shown.

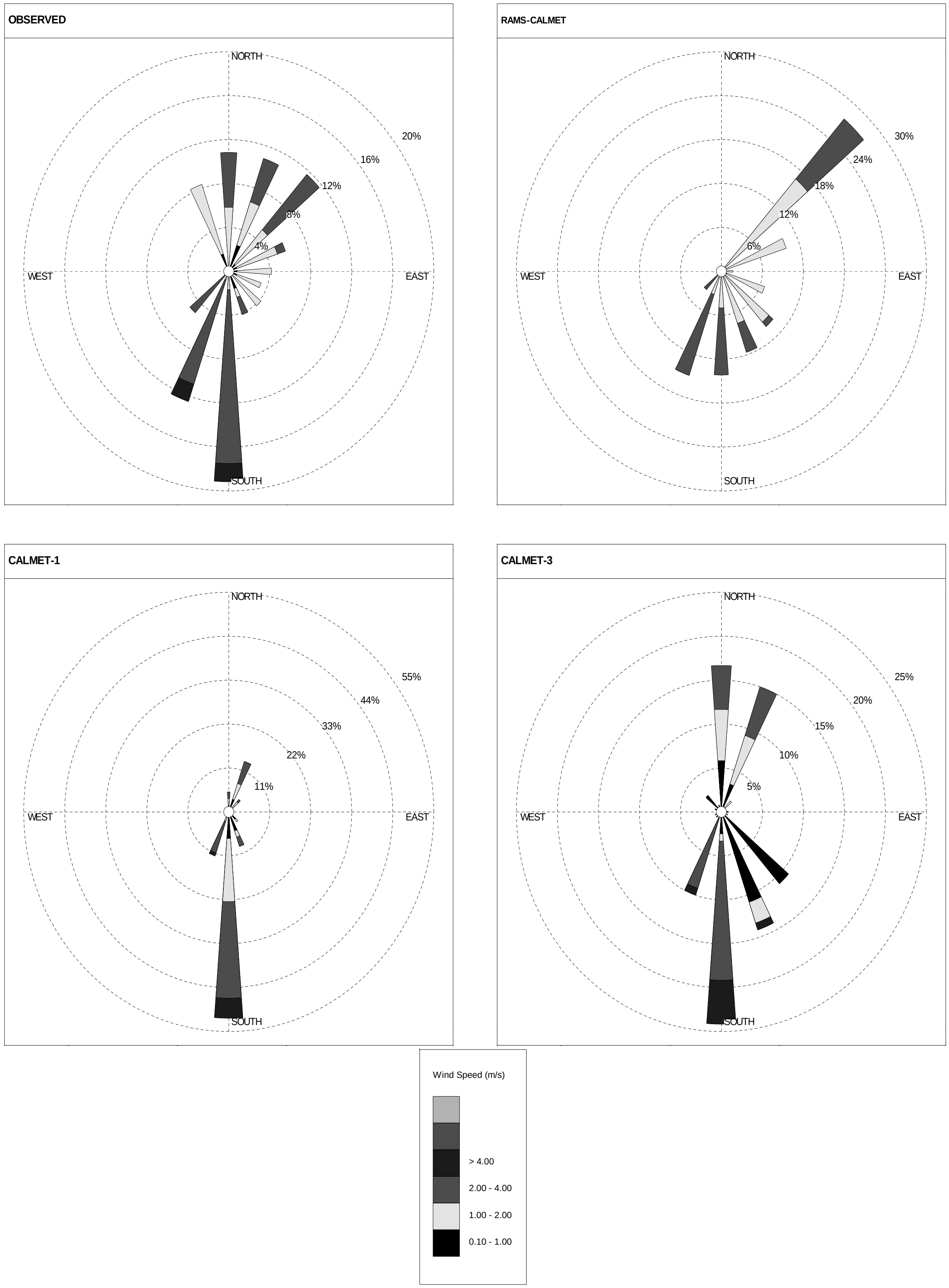


Figure A.18. Windrose diagrams showing observed and modelled winds at GLENVIEW station for the 5-day period January 28 to February 1, 1999.

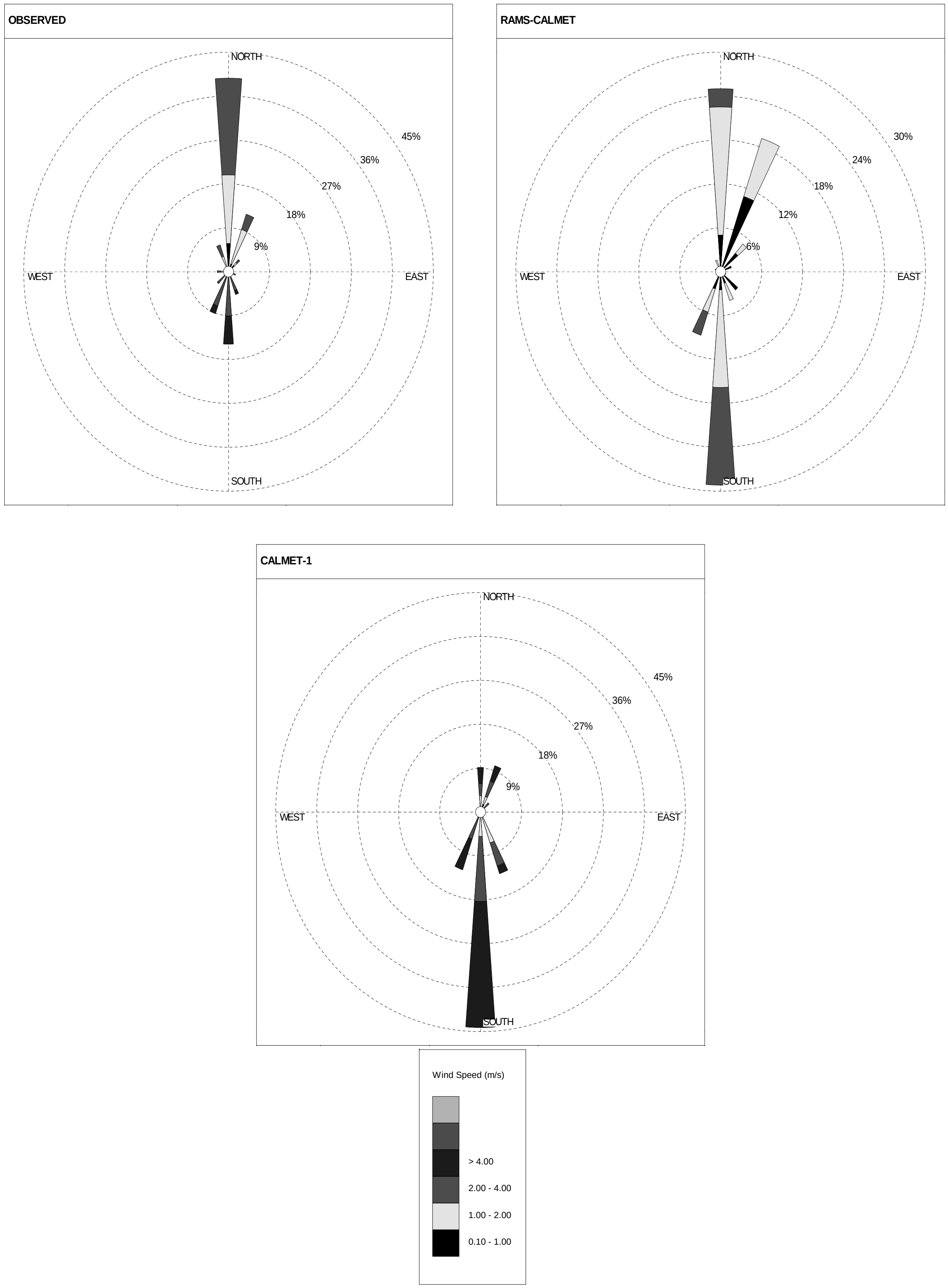


Figure A.19. Windrose diagrams showing observed and modelled winds at NORTHWOOD station for the 5 day period January 28 to February 1, 1999.

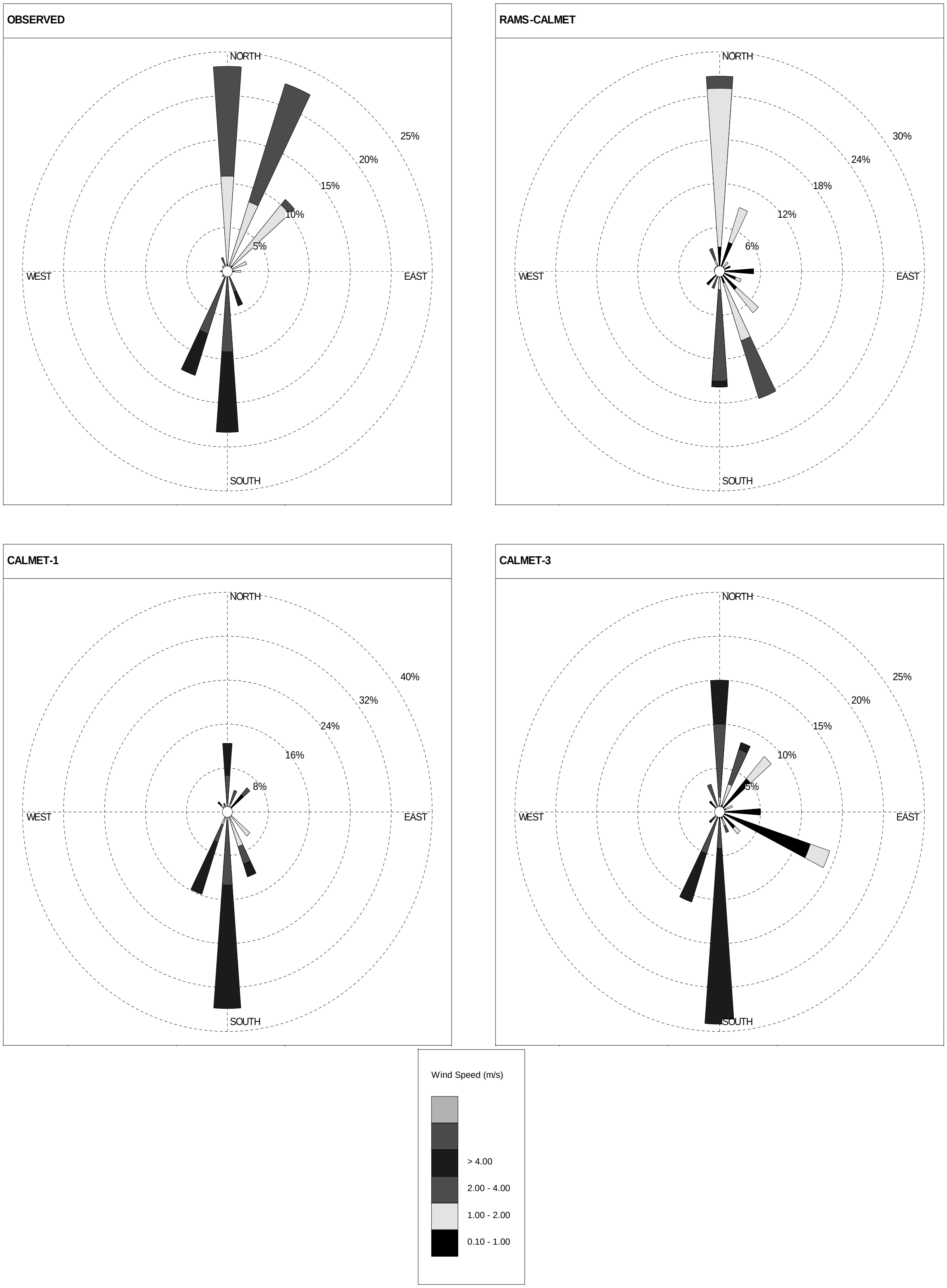


Figure A.20. Windrose diagrams showing observed and modelled winds at P.G. PULP station for the 5 day period January 28 to February 1, 1999.

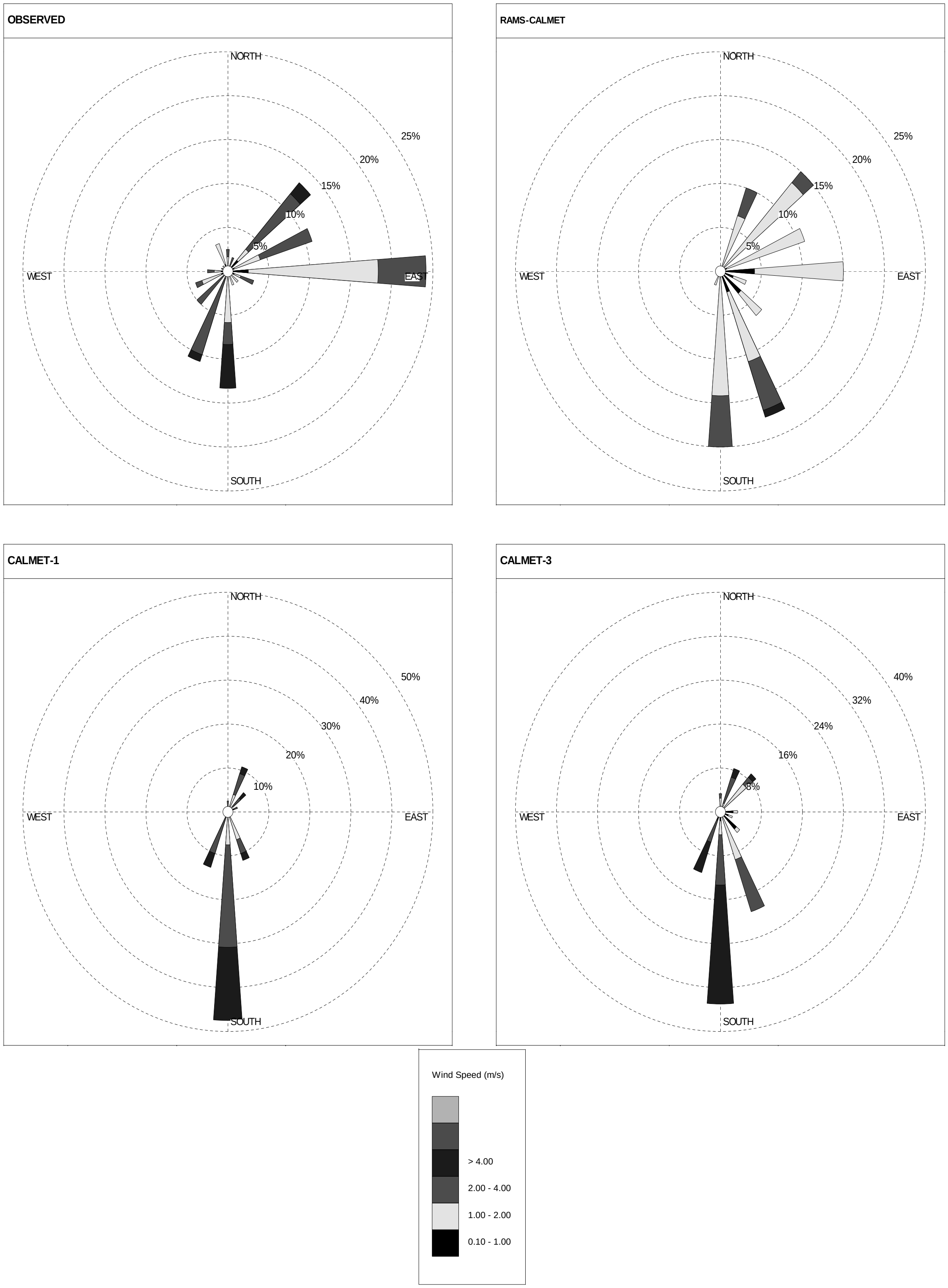


Figure A.21. Windrose diagrams showing observed and modelled winds at PLAZA station for the 5 day period January 28 to February 1, 1999.

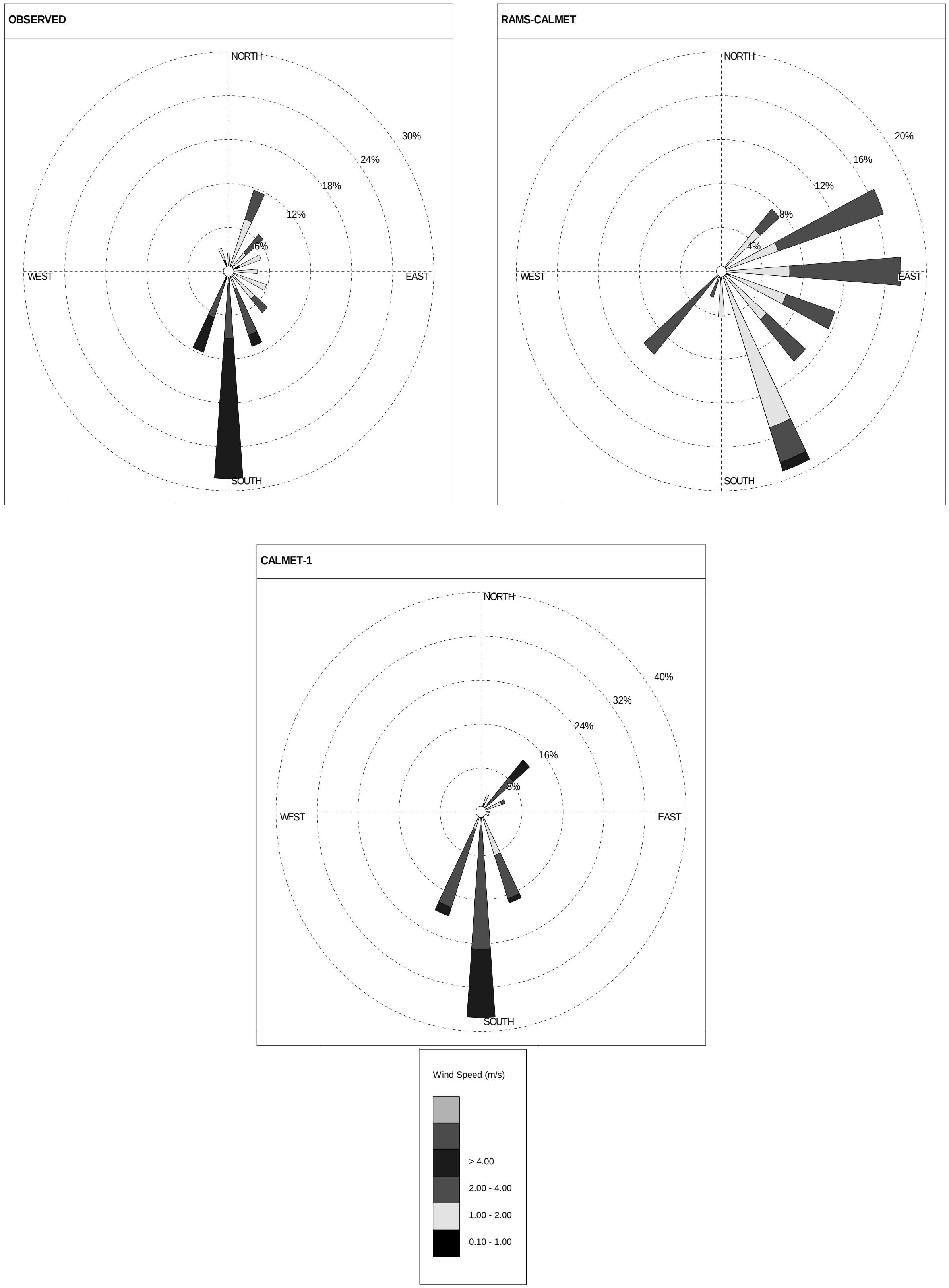


Figure A.22. Windrose diagrams showing observed and modelled winds at UNIVERSITY station for the 5 day period January 28 to February 1, 1999.

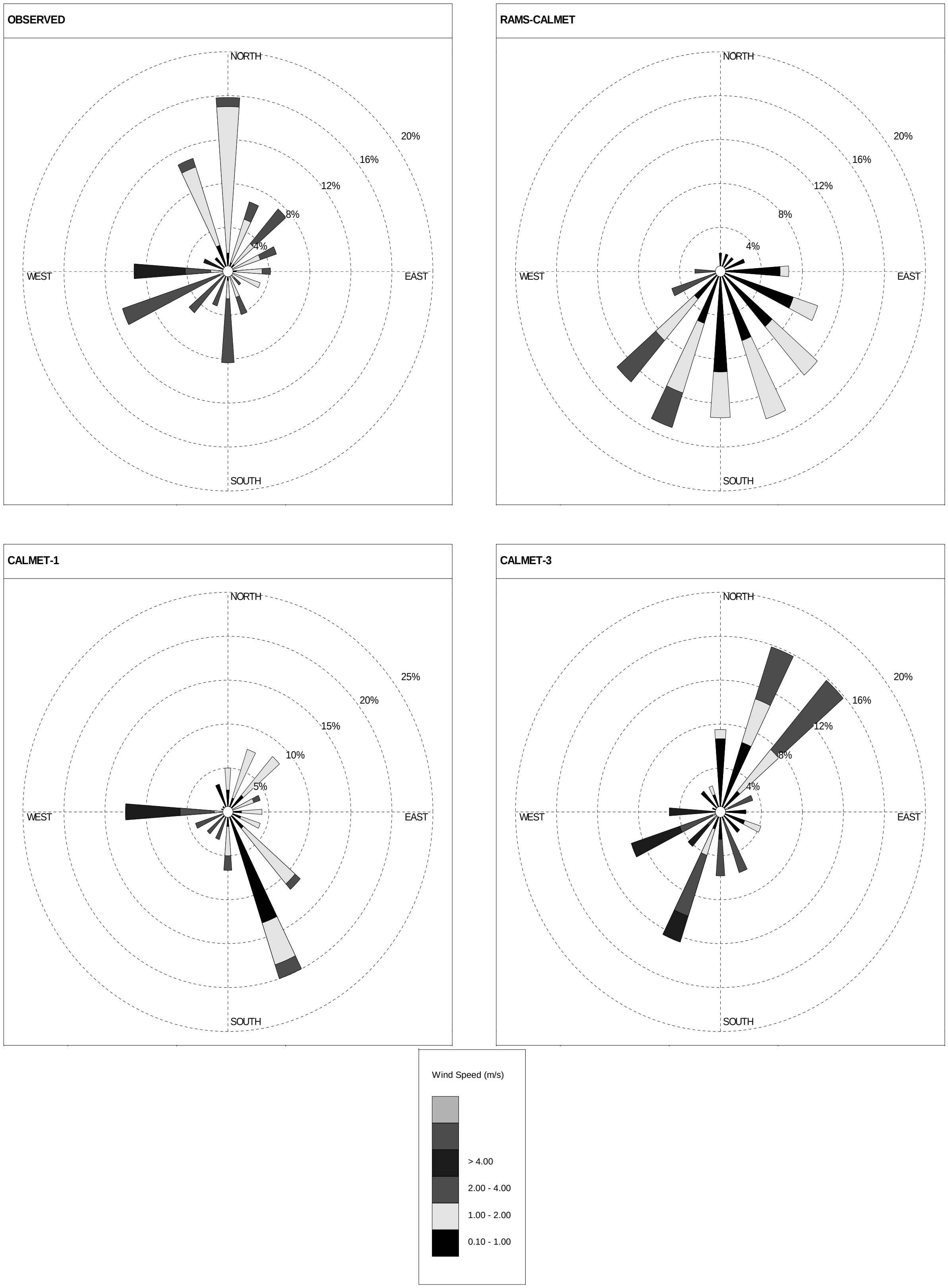


Figure A.23. Windrose diagrams showing observed and modelled winds at GLENVIEW station for the 5 day period April 13 to April 17, 1999.

Figure A.24. Windrose diagrams showing observed and modelled winds at NORTHWOOD station for the 5 day period April 13 to April 17, 1999.

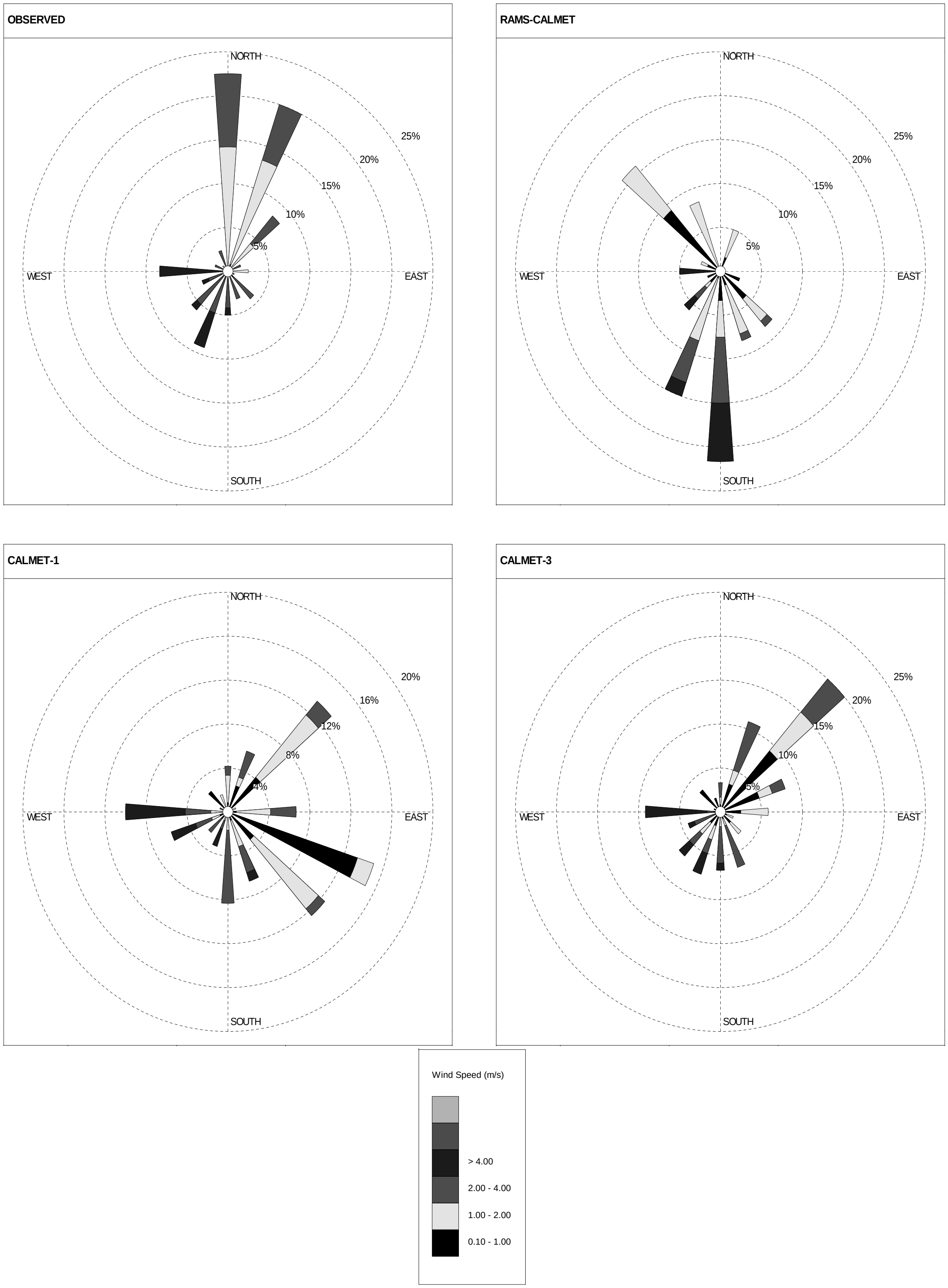


Figure A.25. Windrose diagrams showing observed and modelled winds at P.G. PULP station for the 5 day period April 13 to April 17, 1999.

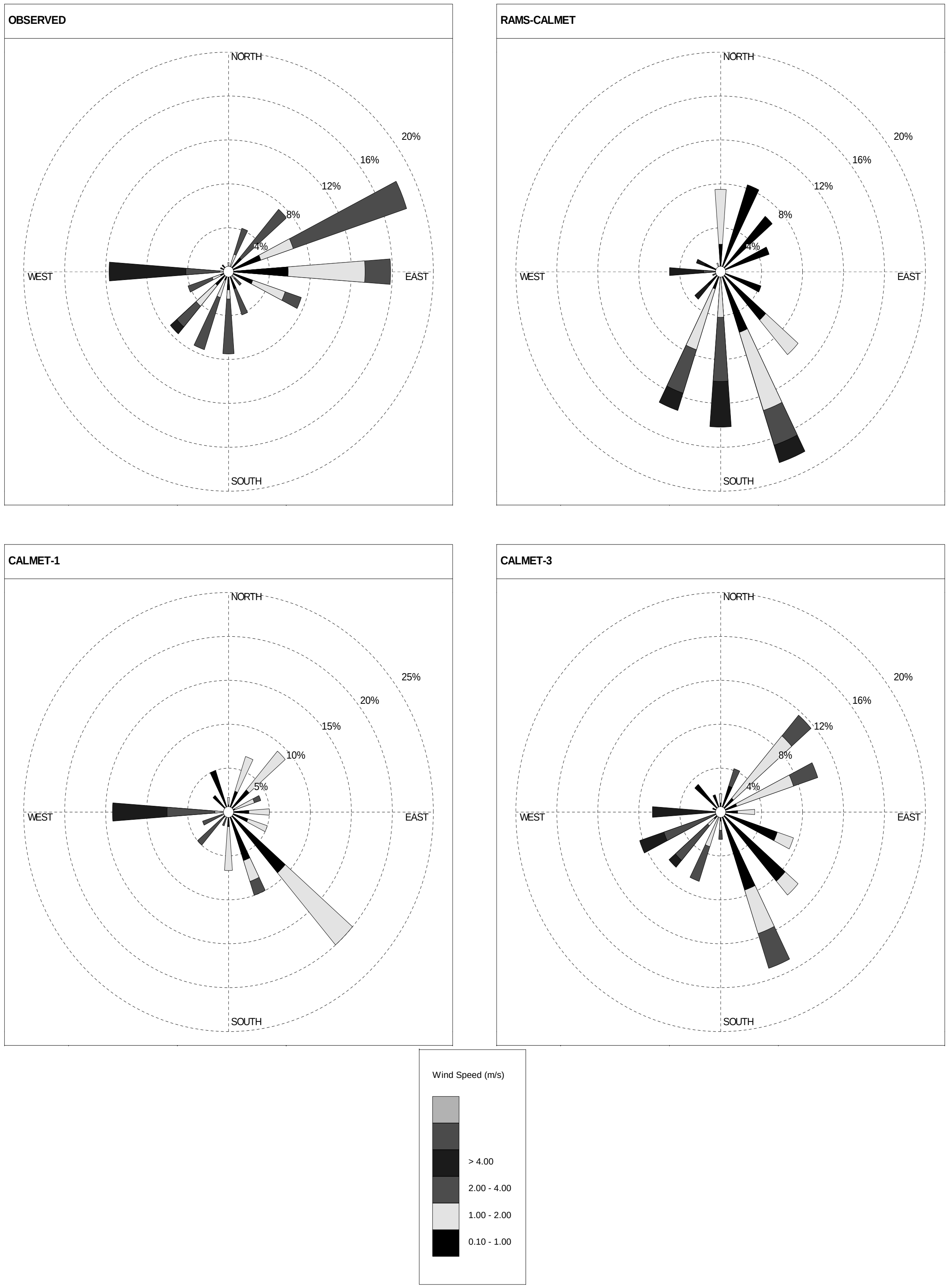


Figure A.26. Windrose diagrams showing observed and modelled winds at PLAZA station for the 5 day period April 13 to April 17, 1999.

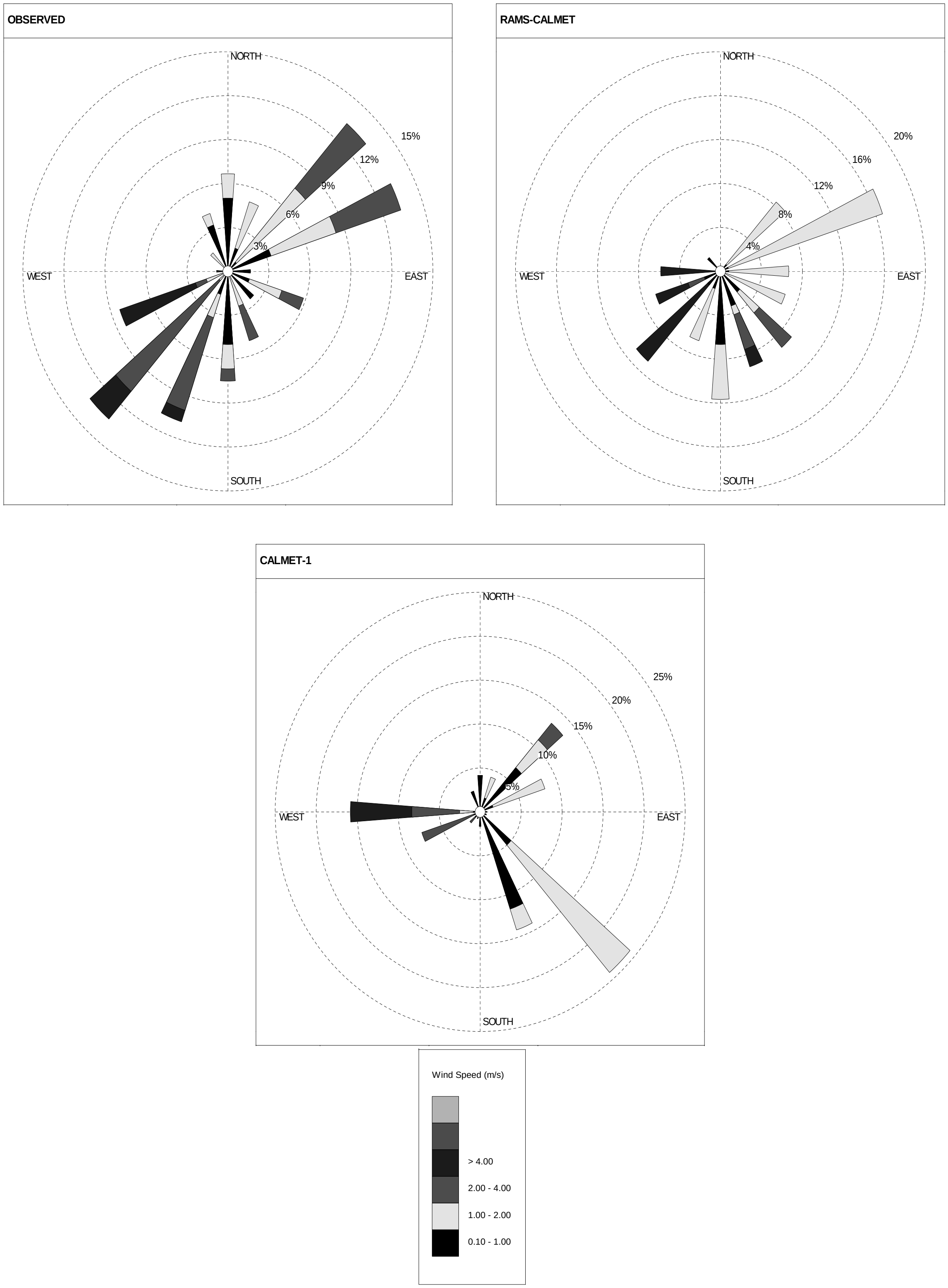


Figure A.27. Windrose diagrams showing observed and modelled winds at UNIVERSITY station for the 5 day period April 13 to April 17, 1999.

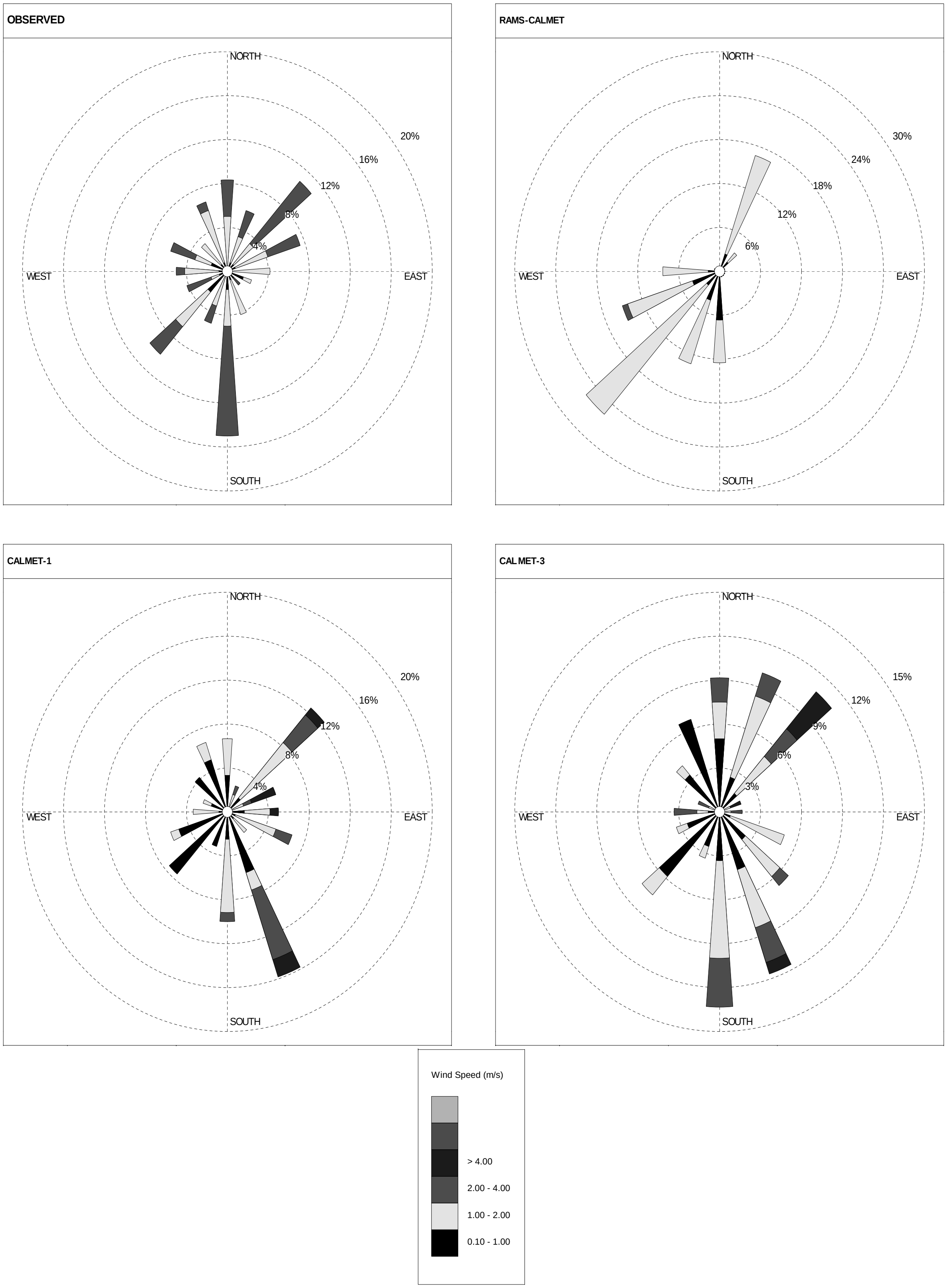


Figure A.28. Windrose diagrams showing observed and modelled winds at GLENVIEW station for the 5 day period June 8 to June 12, 1999.

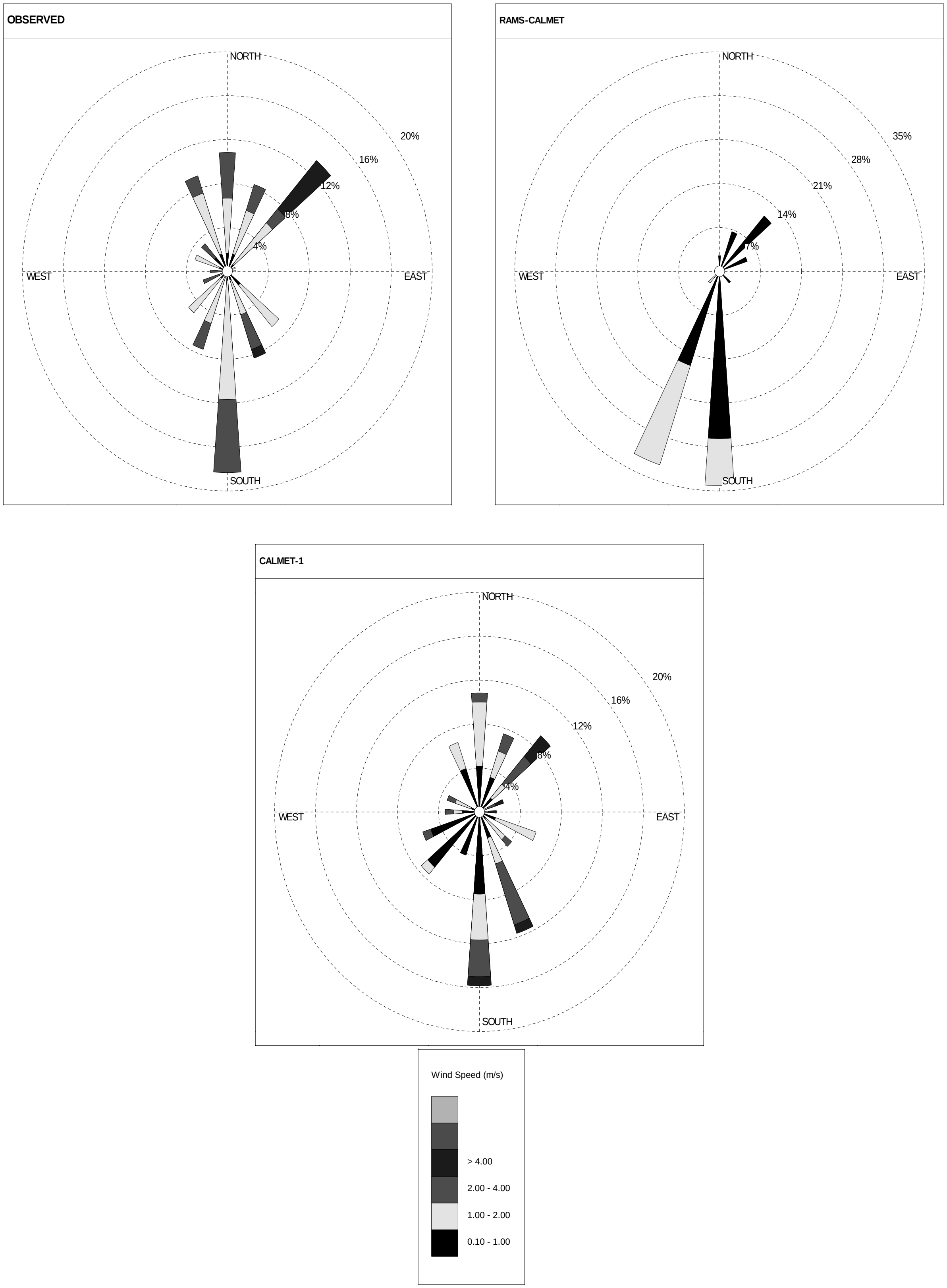


Figure A.29. Windrose diagrams showing observed and modelled winds at NORTHWOOD station for the 5 day period June 8 to June 12, 1999.

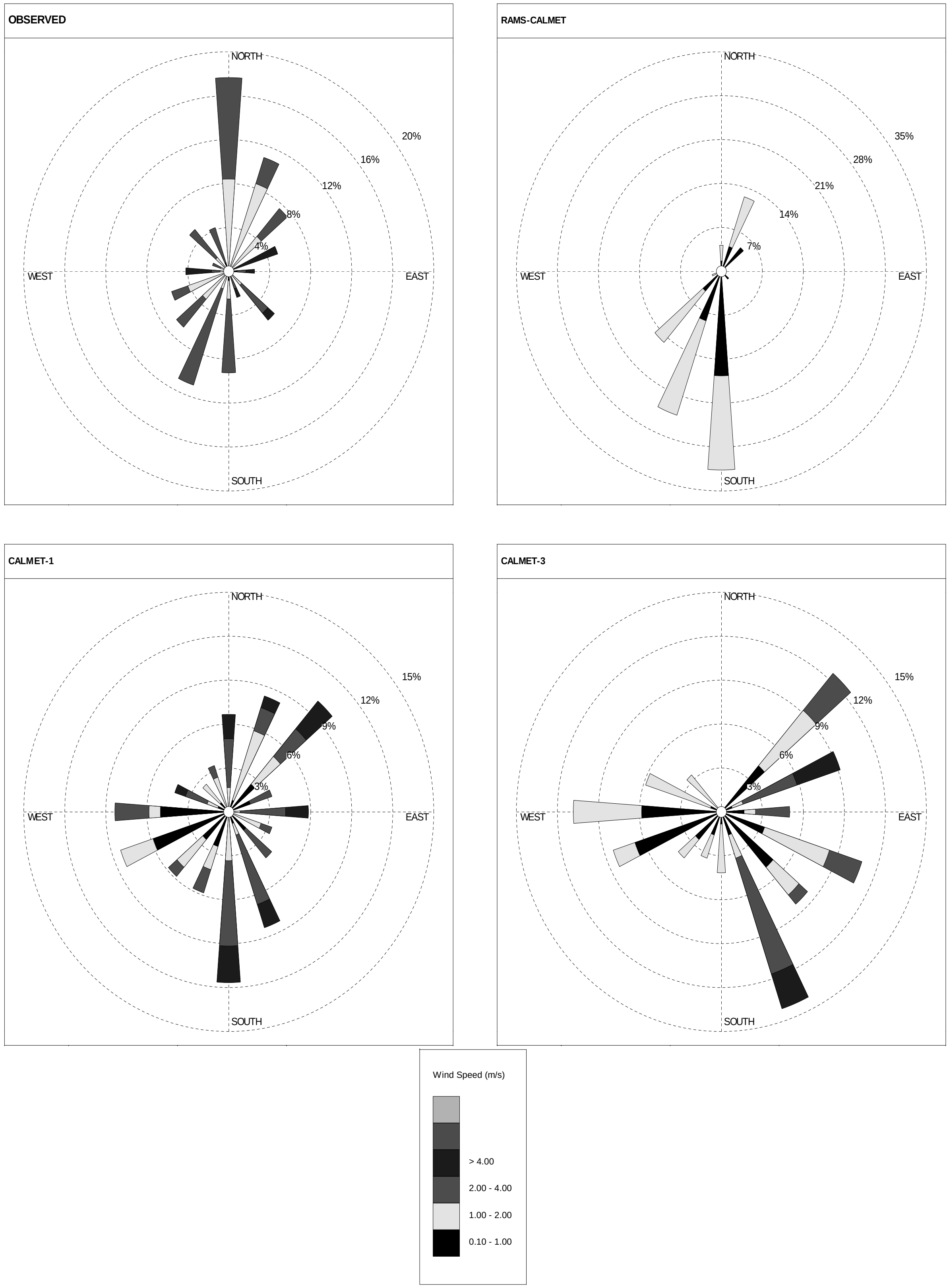


Figure A.30. Windrose diagrams showing observed and modelled winds at P.G. PULP station for the 5 day period June 8 to June 12, 1999.

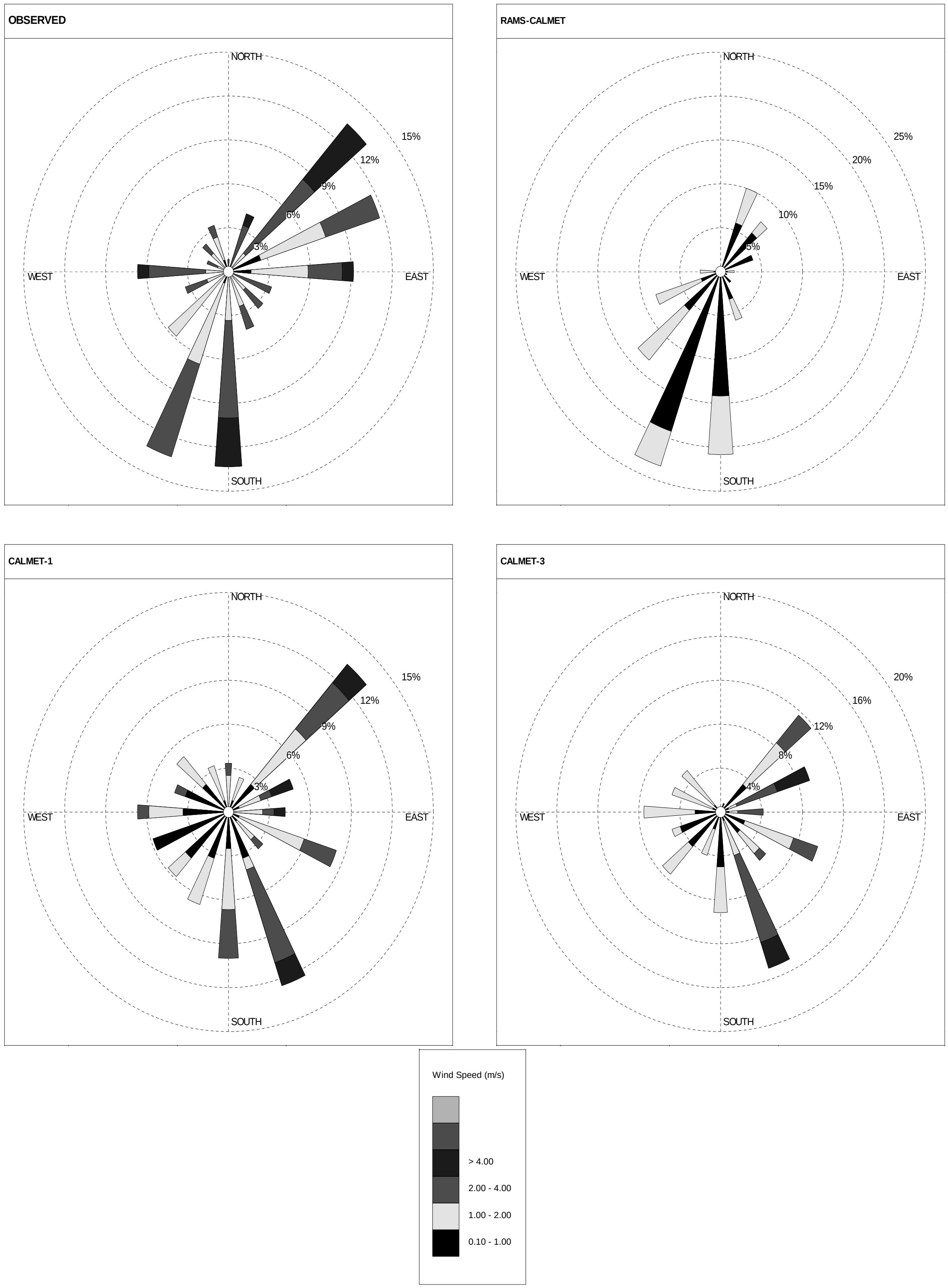


Figure A.31. Windrose diagrams showing observed and modelled winds at PLAZA station for the 5 day period June 8 to June 12, 1999.

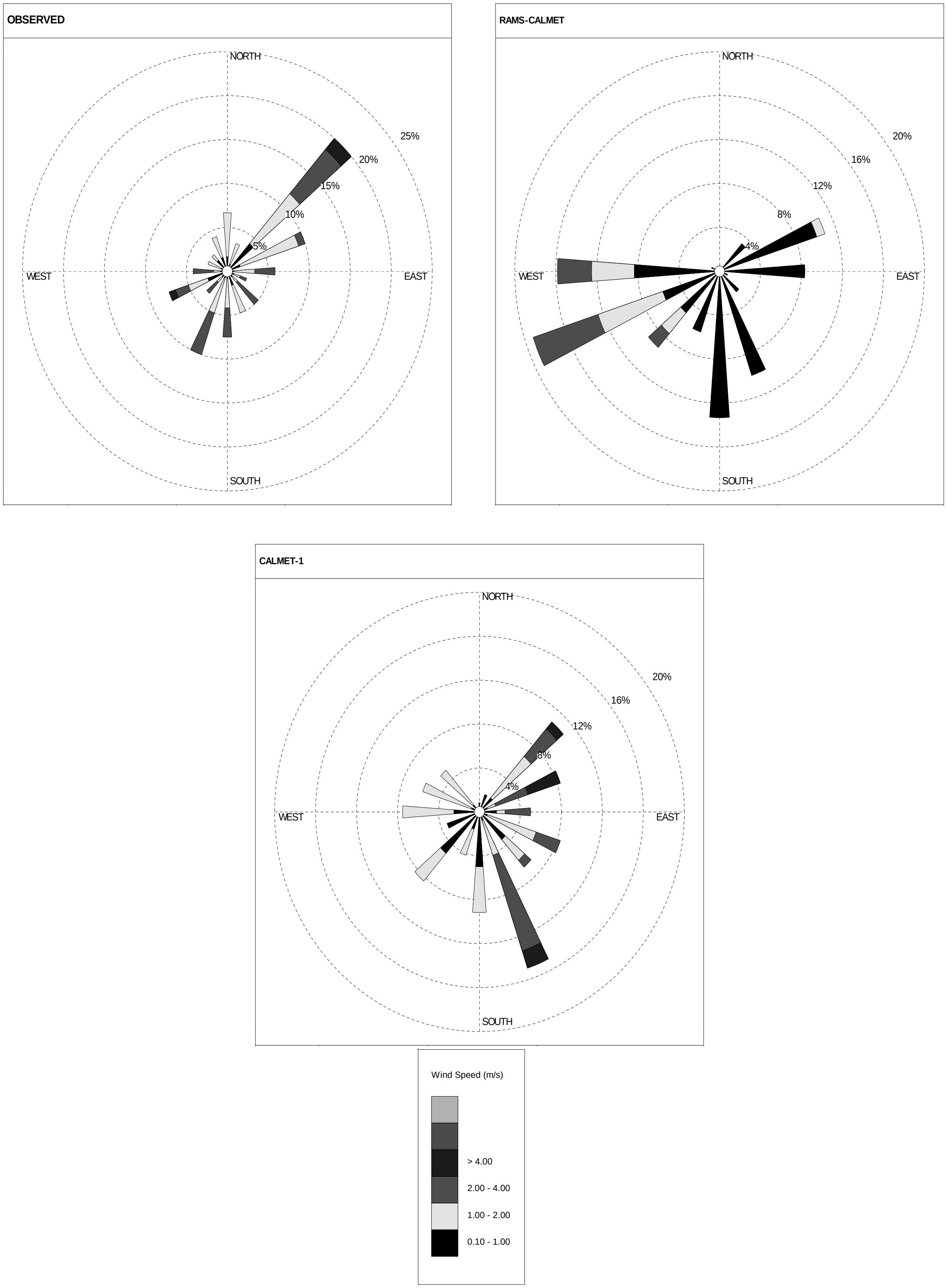


Figure A.32. Windrose diagrams showing observed and modelled winds at UNIVERSITY station for the 5 day period June 8 to June 12, 1999.

A.5. Sulphur Dioxide Concentrations

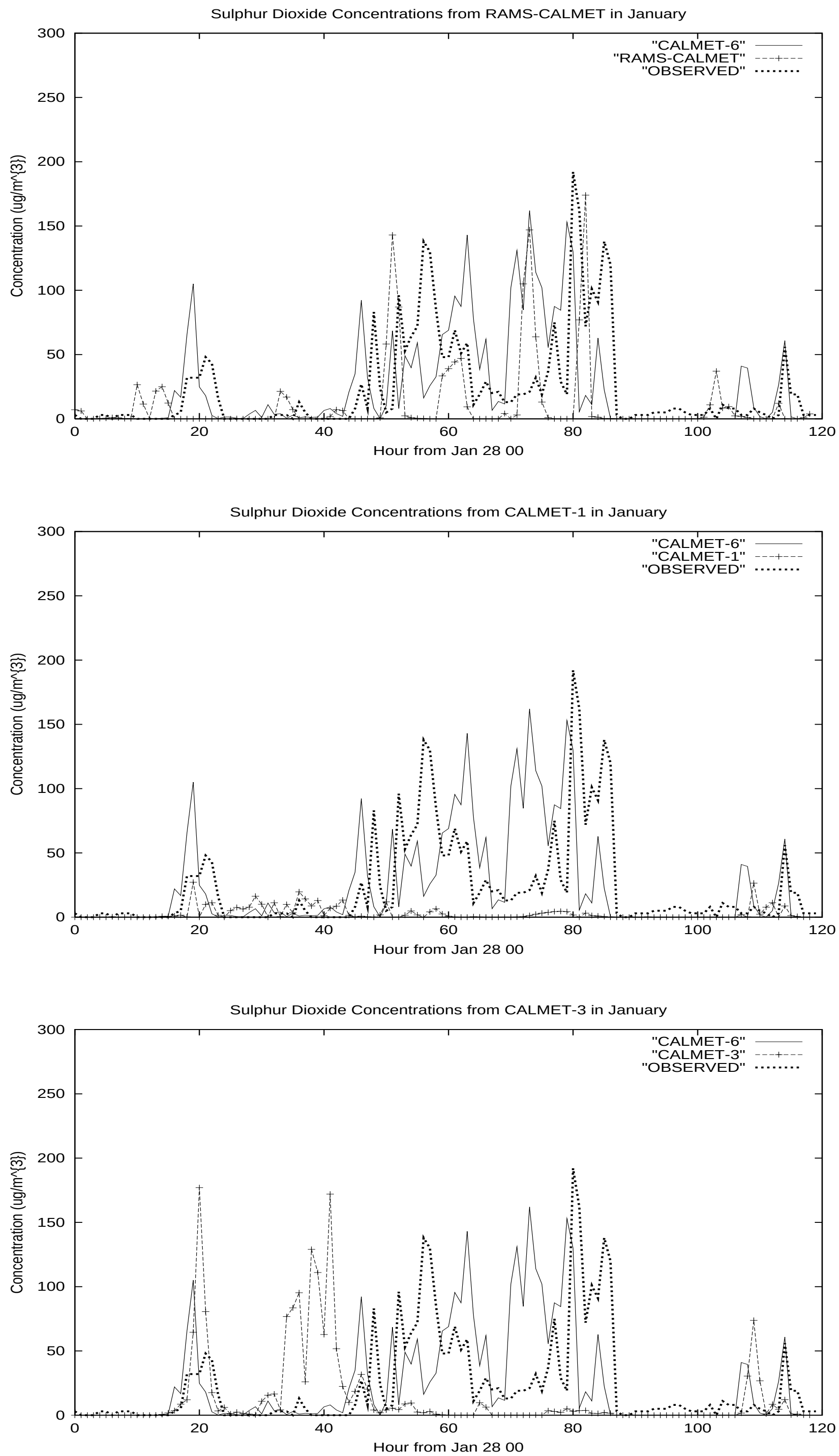


Figure A.33. Modelled SO_2 for Plaza station, January 28 to February 1. RAMS-CALMET, CALMET-1 and CALMET-3 values shown, with Observed and CALMET-6 concentrations shown in each graph for comparison.

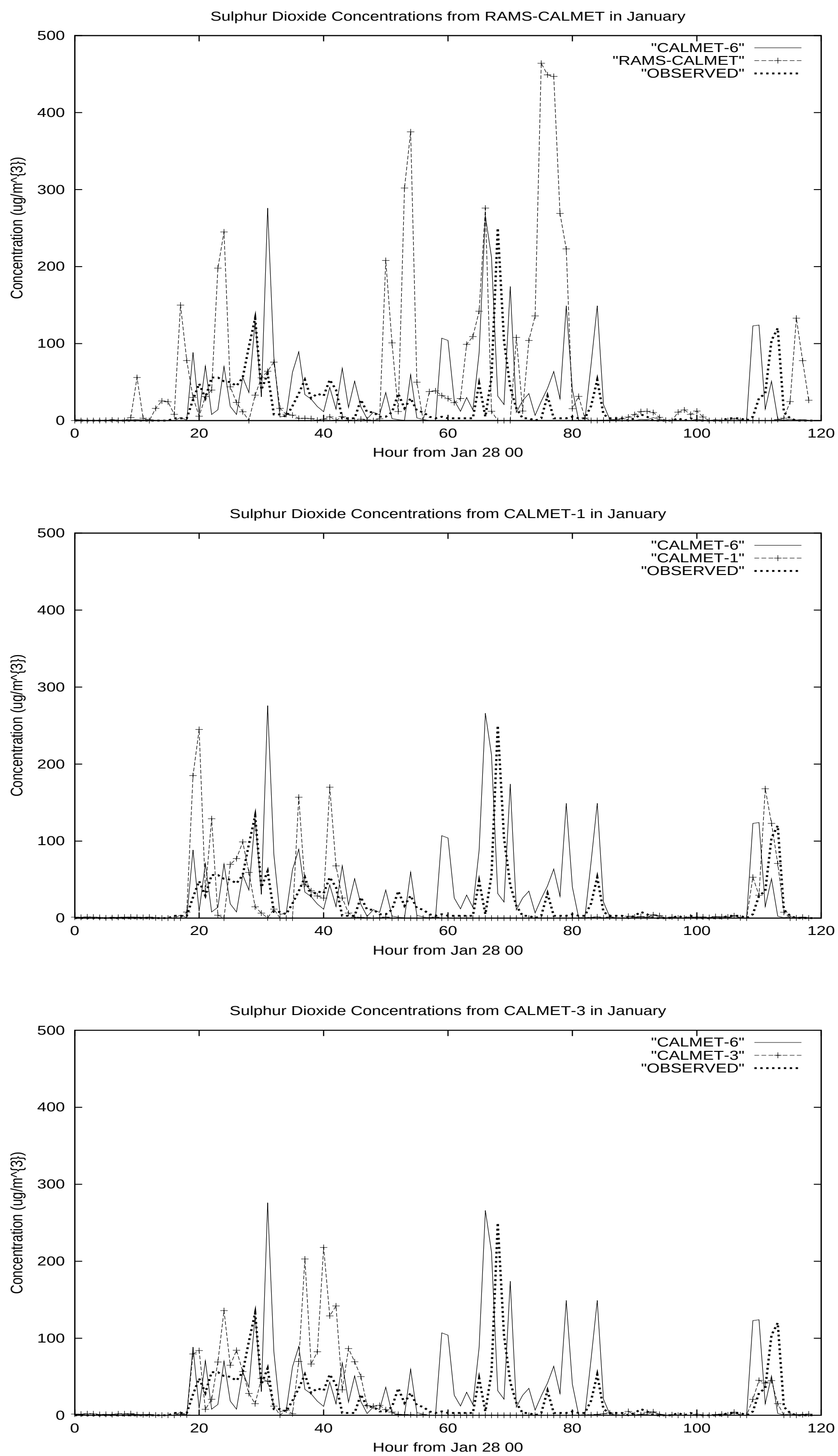


Figure A.34. Modelled SO_2 for Jail station, January 28 to February 1. RAMS-CALMET, CALMET-1 and CALMET-3 values shown, with Observed and CALMET-6 concentrations shown in each graph for comparison.

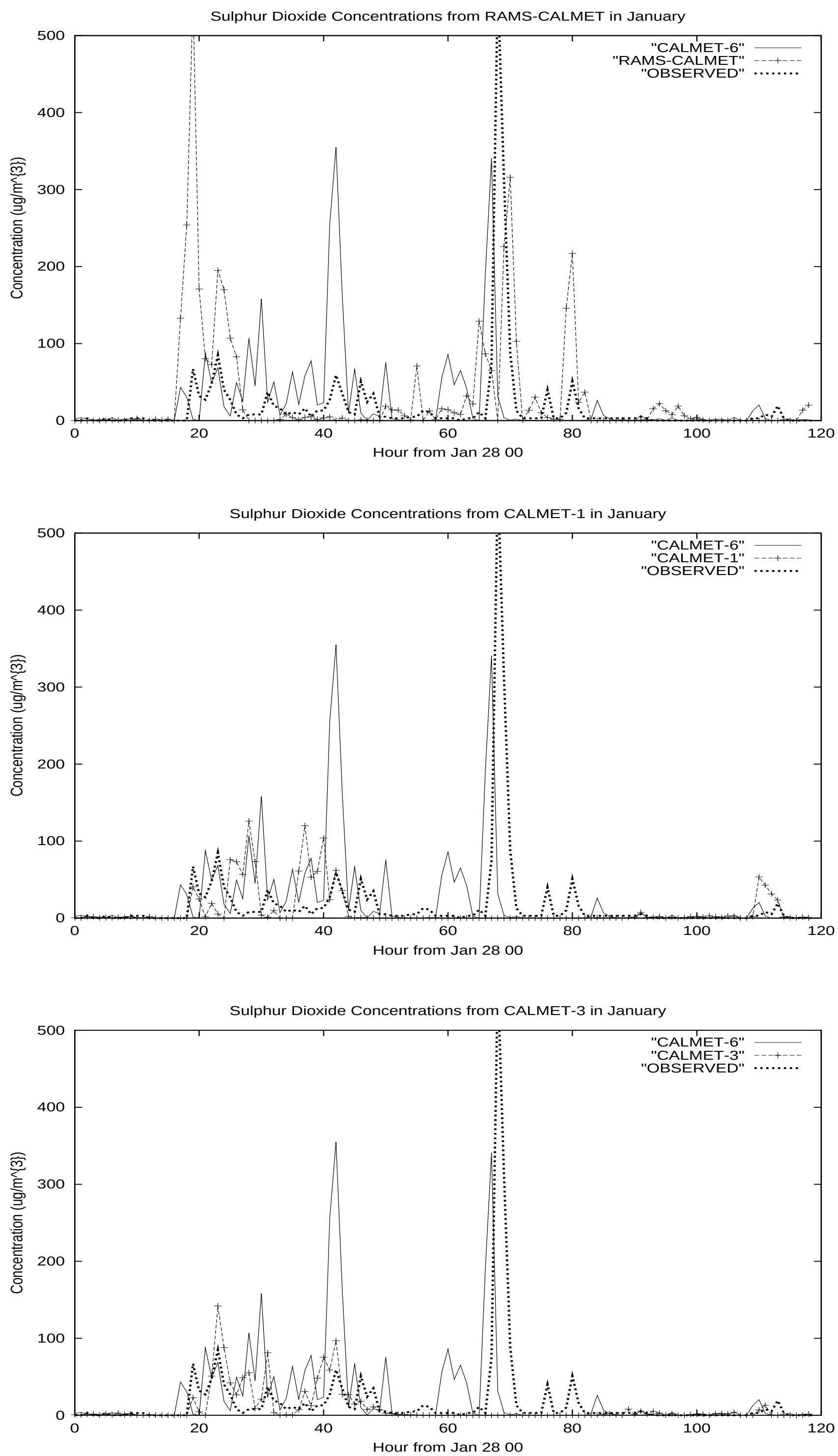


Figure A.35. Modelled SO_2 for CBC station, January 28 to February 1. RAMS-CALMET, CALMET-1 and CALMET-3 values, with Observed and CALMET-6 concentrations shown in each graph for comparison.

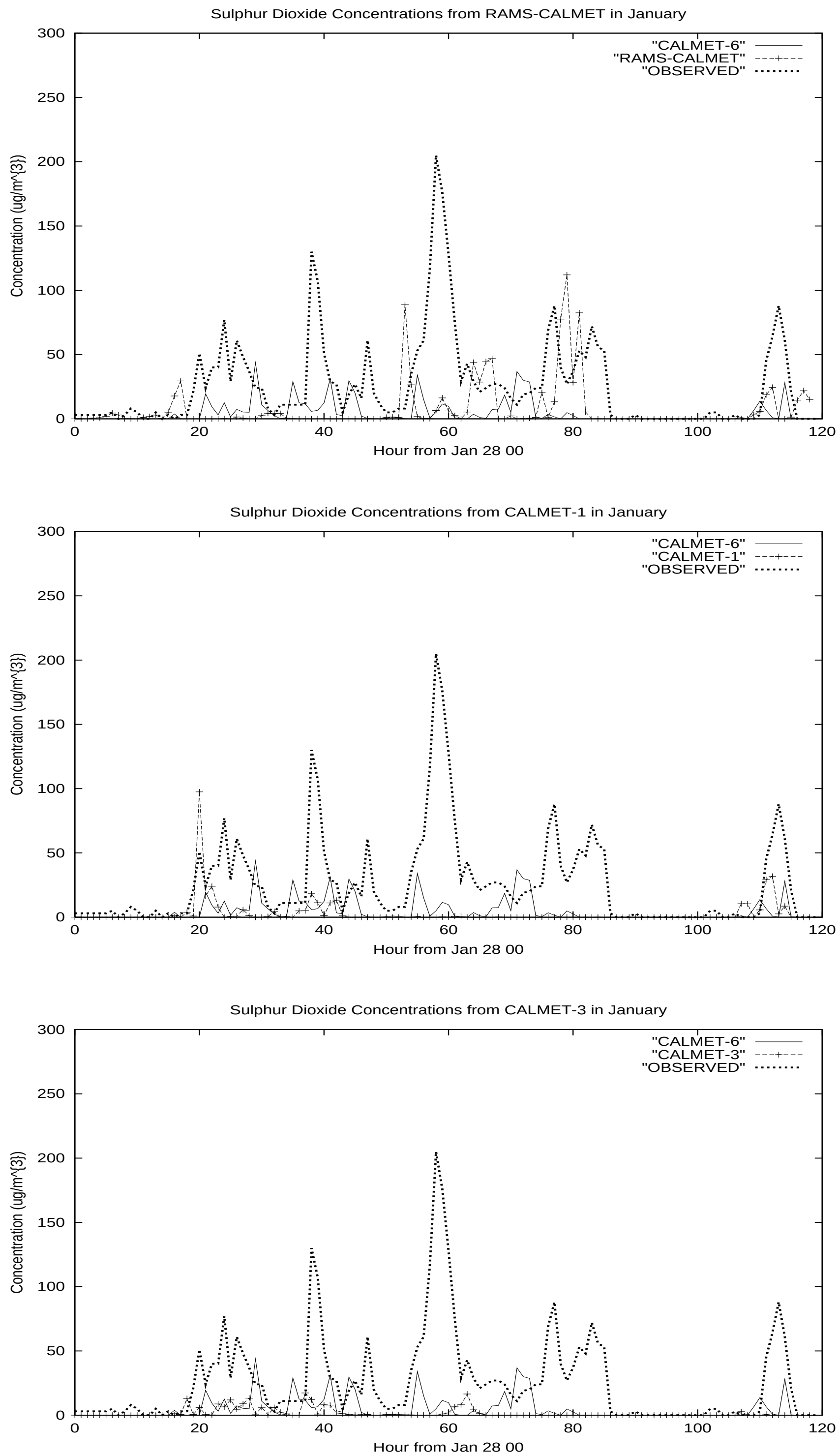


Figure A.36. Modelled SO_2 for Gladstone station, January 28 to February 1. RAMS-CALMET, CALMET-1 and CALMET-3 values, with Observed and CALMET-6 concentrations shown in each graph for comparison.

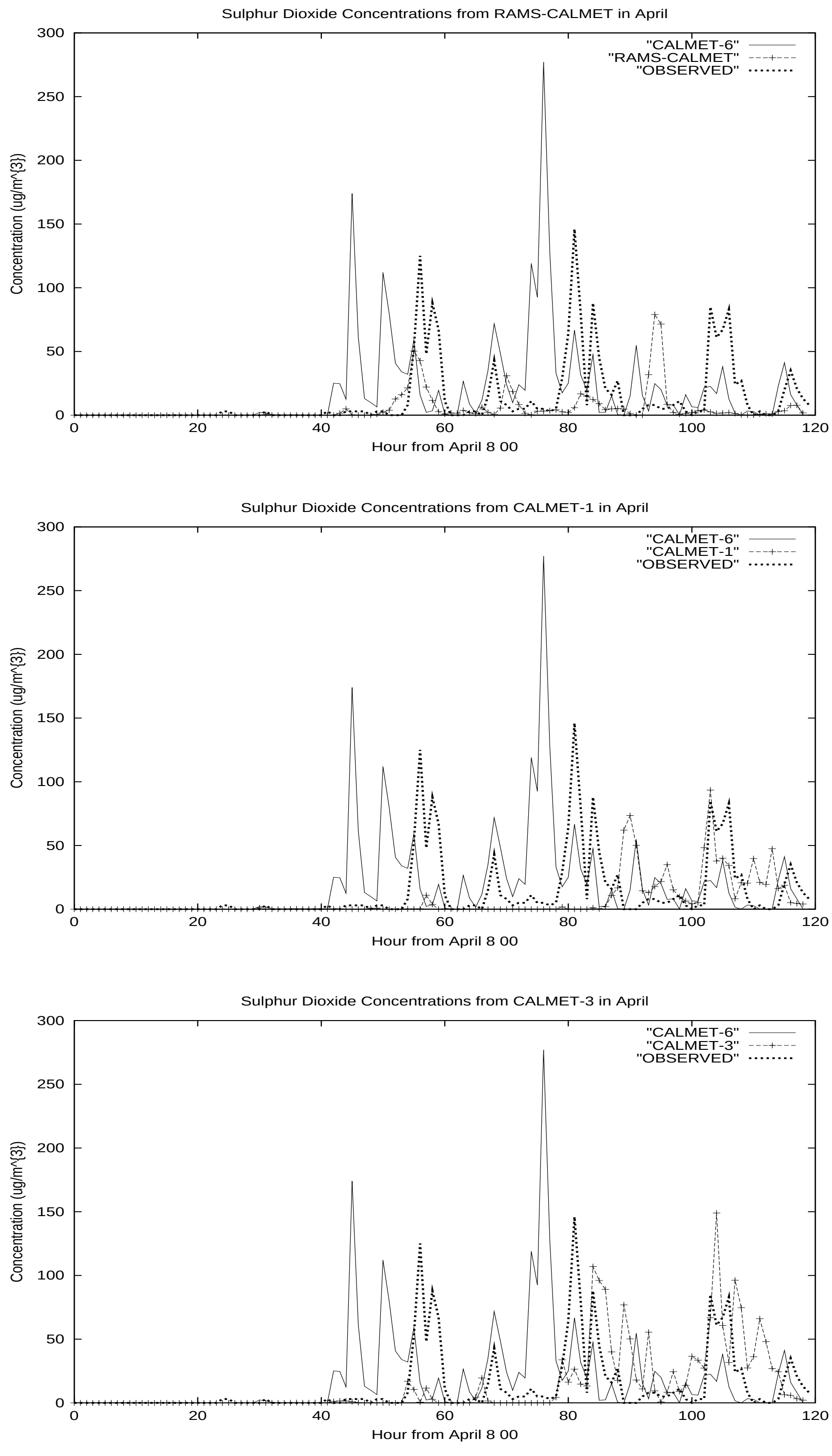


Figure A.37. Modelled SO_2 for Plaza station, April 13 to 17. RAMS-CALMET, CALMET-1 and CALMET-3 values, with Observed and CALMET-6 concentrations shown in each graph for comparison.

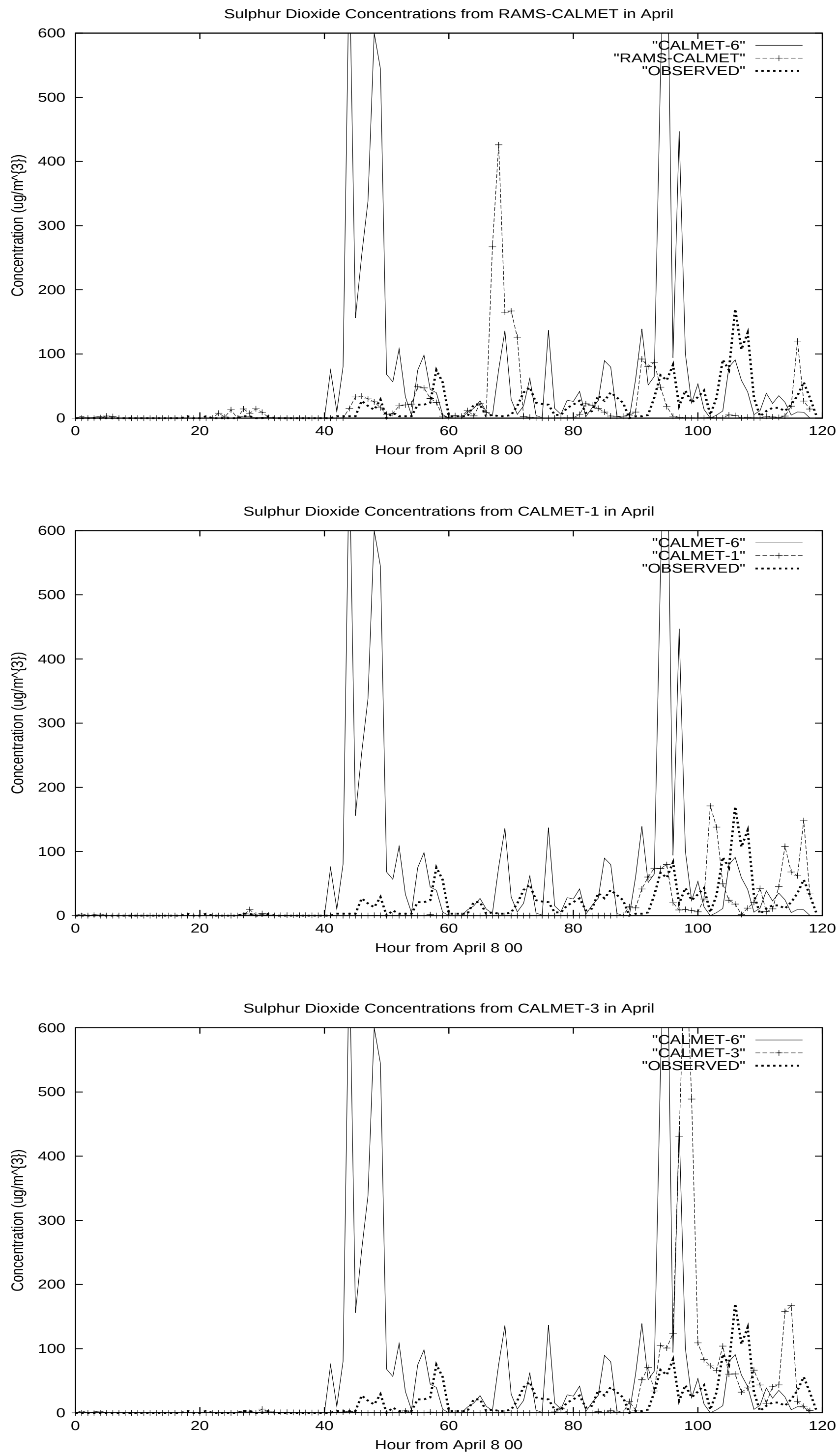


Figure A.38. Modelled SO_2 for Jail station, April 13 to 17. RAMS-CALMET, CALMET-1 and CALMET-3 values, with Observed and CALMET-6 concentrations shown in each graph for comparison.

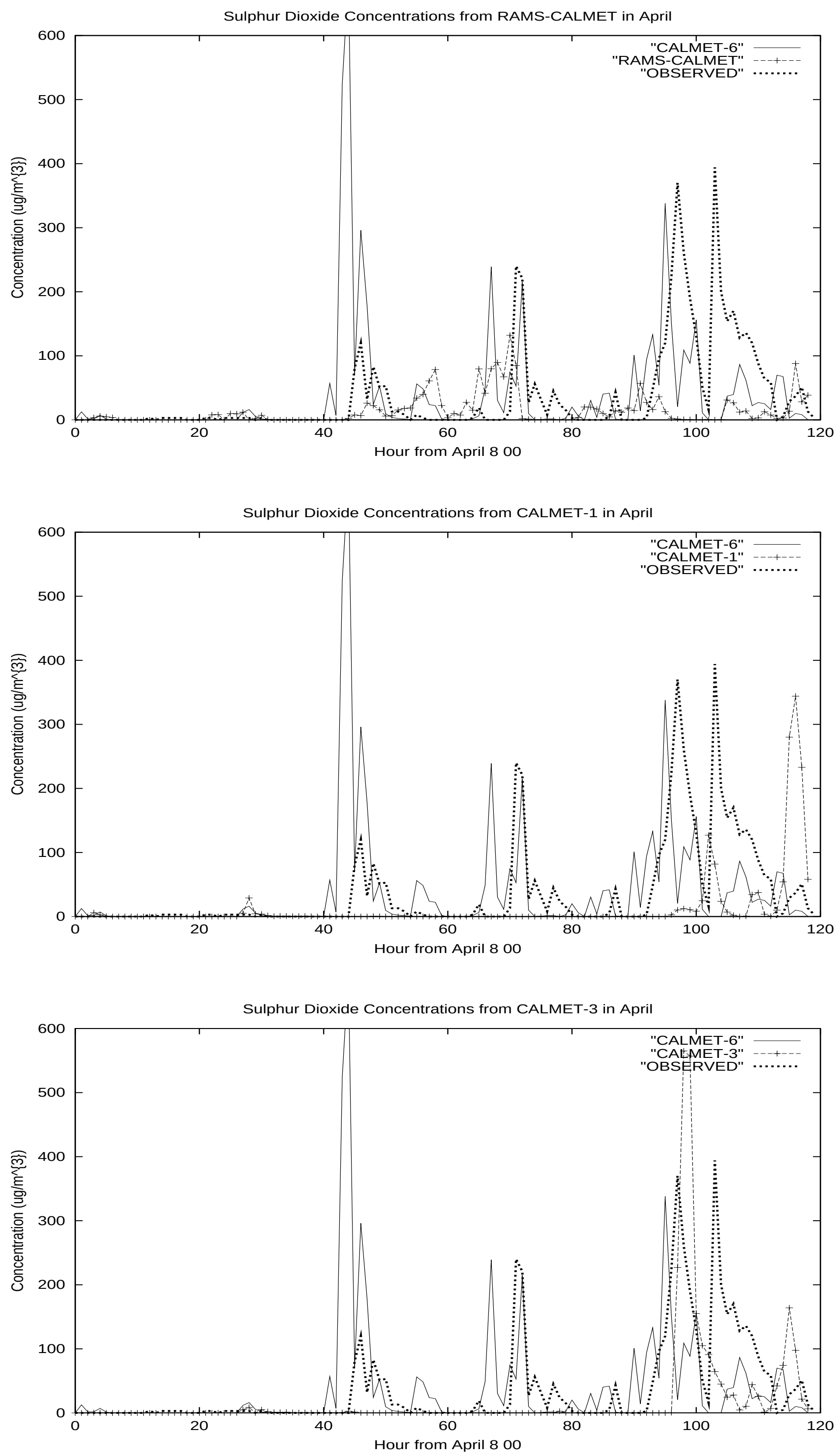


Figure A.39. Modelled SO_2 for CBC station, April 13 to 17. RAMS-CALMET, CALMET-1 and CALMET-3 values, with Observed and CALMET-6 concentrations shown in each graph for comparison.

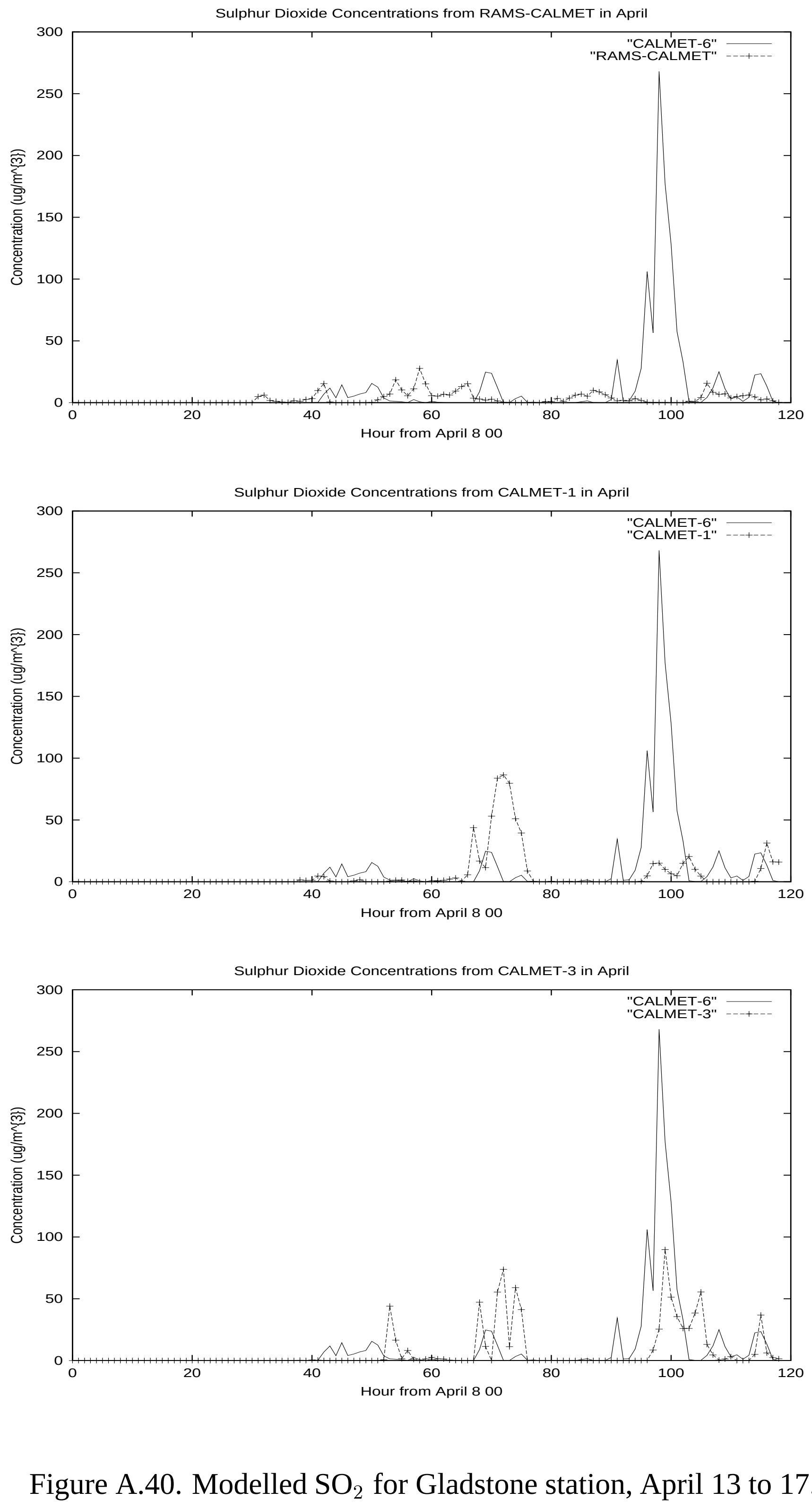


Figure A.40. Modelled SO_2 for Gladstone station, April 13 to 17. RAMS-CALMET, CALMET-1 and CALMET-3 values, with CALMET-6 concentrations shown in each graph for comparison. Observed concentrations were not available.

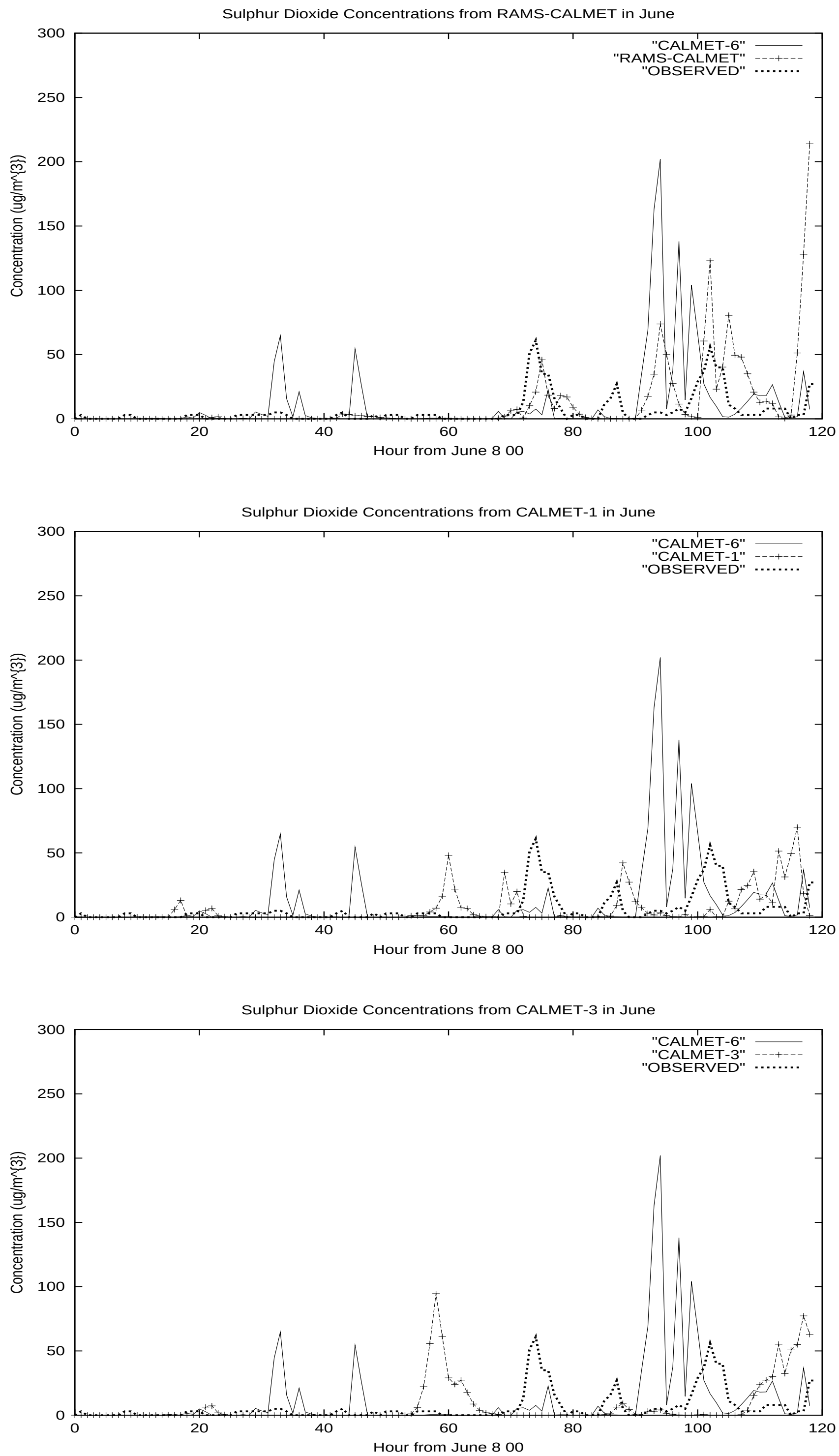
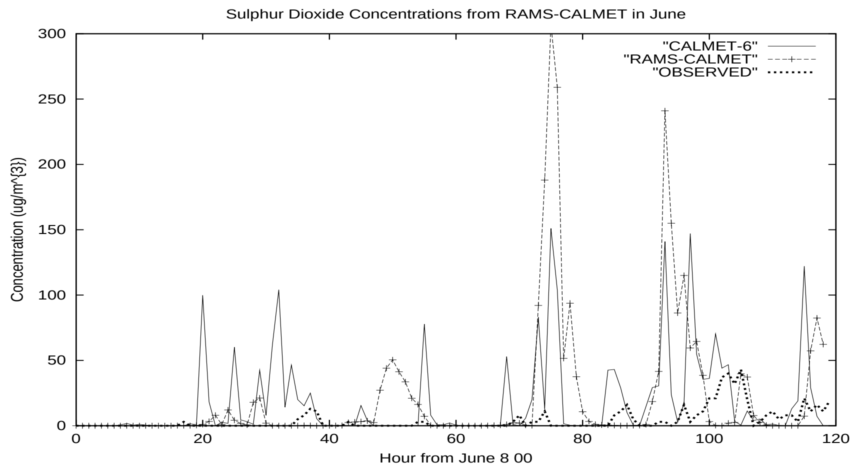
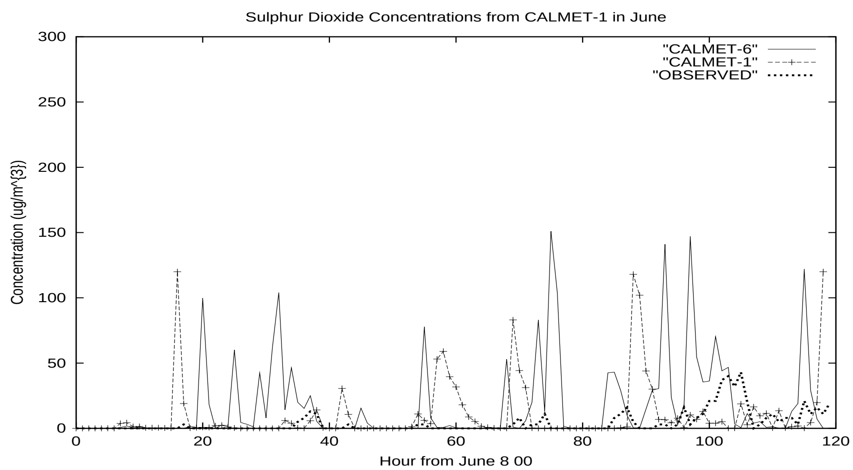


Figure A.41. Modelled SO_2 for Plaza station, June 8 to 12. RAMS-CALMET, CALMET-1 and CALMET-3 values, with Observed and CALMET-6 concentrations shown in each graph for comparison.





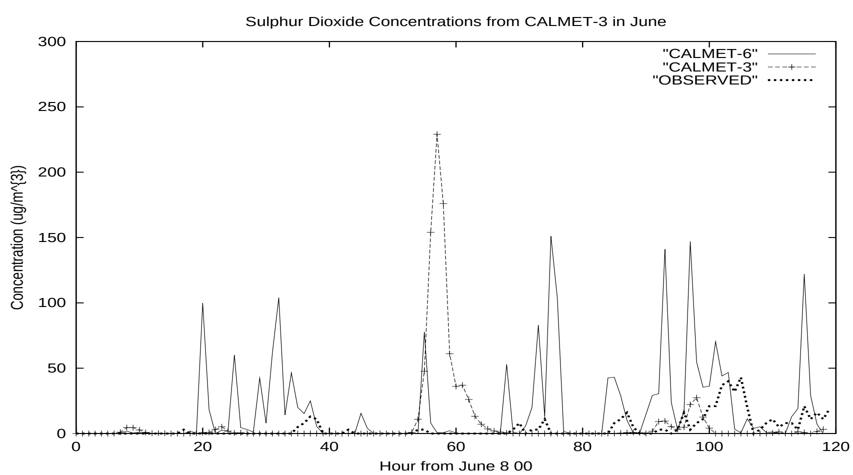


Figure A.42. Modelled SO_2 for Jail station, June 8 to 12. RAMS-CALMET, CALMET-1 and CALMET-3 values, with Observed and CALMET-6 concentrations shown in each graph for comparison.

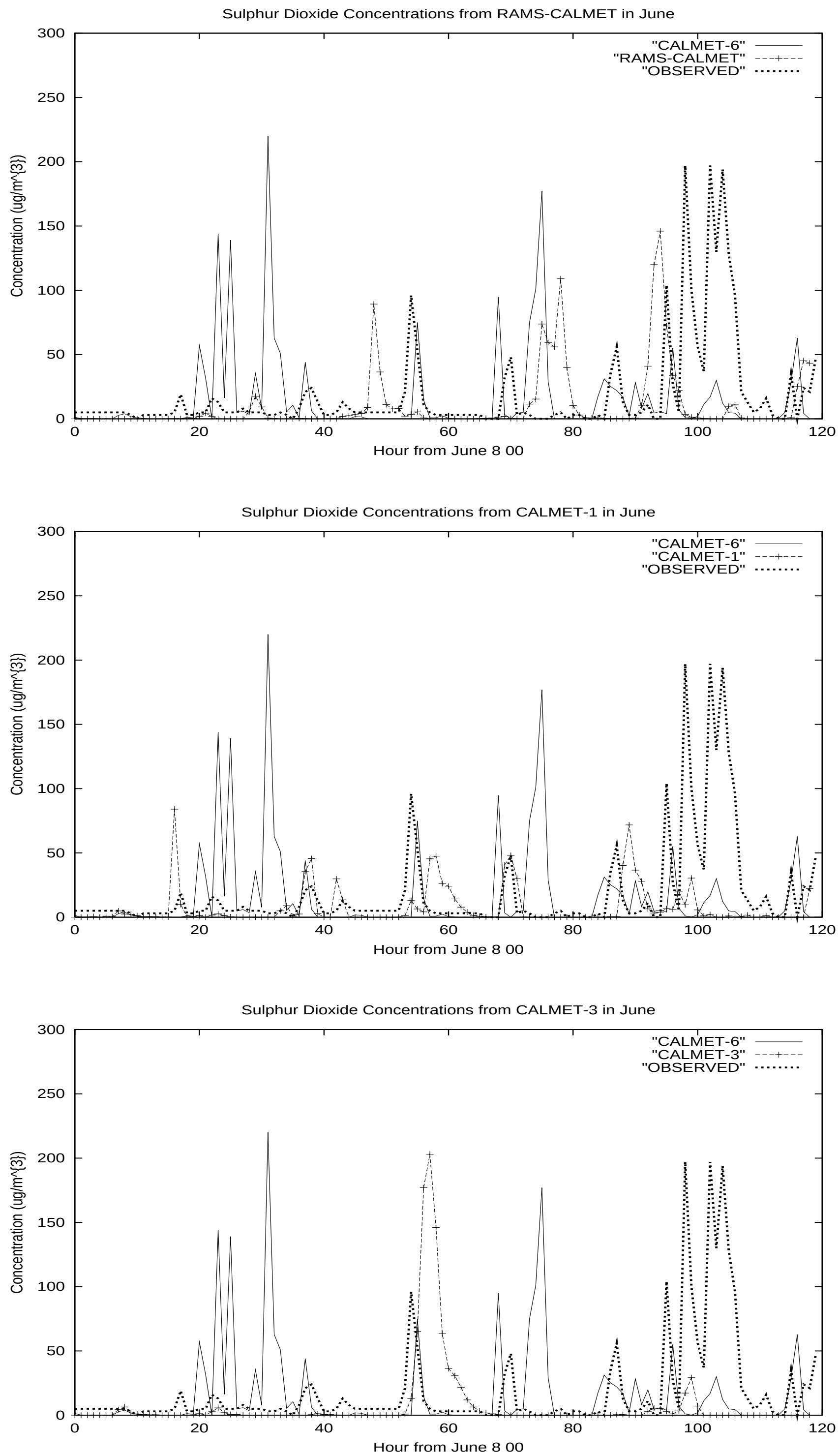


Figure A.43. Modelled SO_2 for CBC station, June 8 to 12. RAMS-CALMET, CALMET-1 and CALMET-3 values, with Observed and CALMET-6 concentrations shown in each graph for comparison.

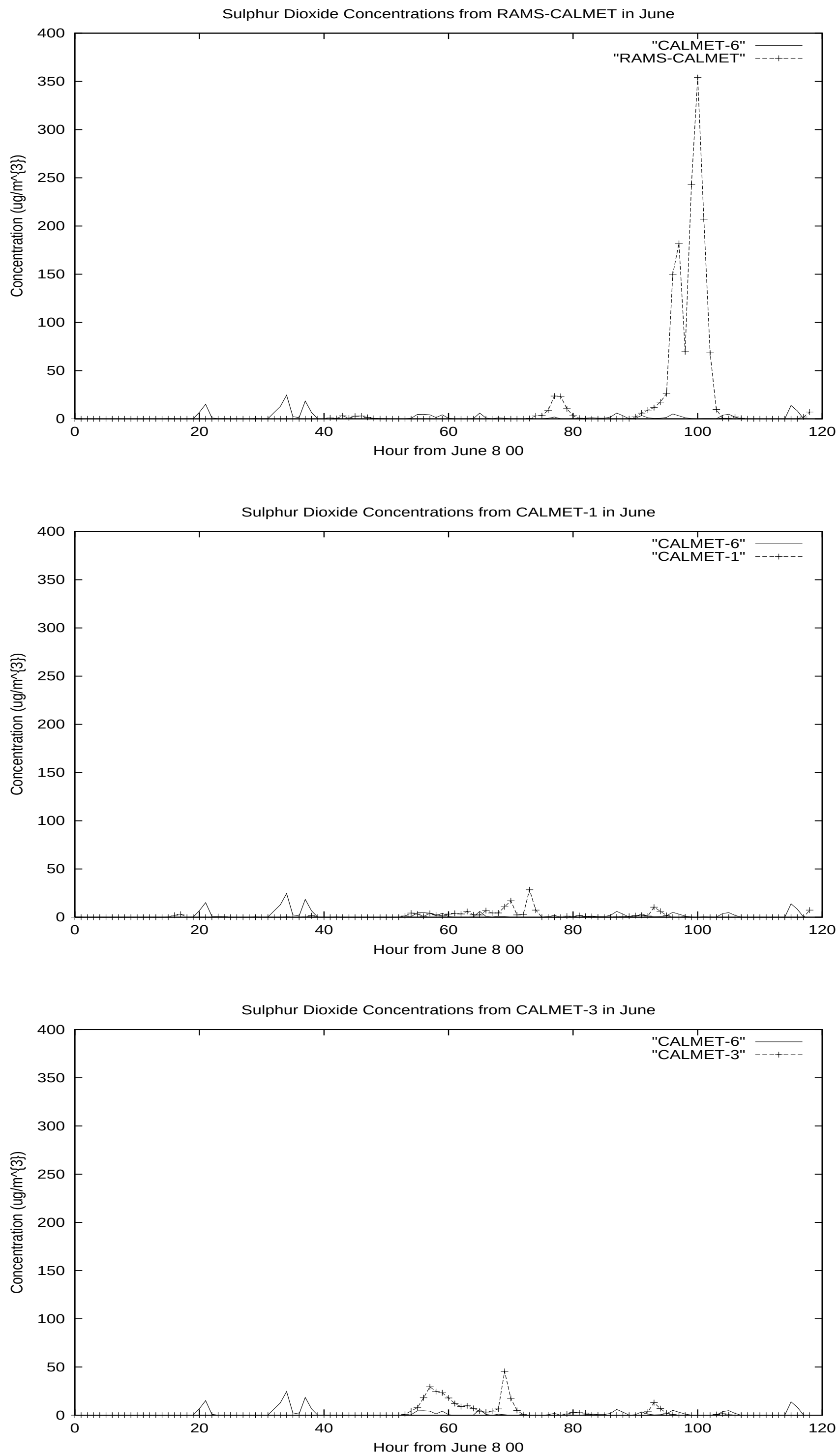


Figure A.44. Modelled SO_2 for Gladstone station, June 8 to 12. RAMS-CALMET, CALMET-1 and CALMET-3 values, with CALMET-6 concentrations shown in each graph for comparison. Observed concentrations were not available.

APPENDIX B

B.6. 24-Hour SO_2 Concentrations

DAY	MODEL	PLAZA	JAIL	CBC	GLADSTONE
Jan 28	OBSERVED	9.3	7.4	8.2	8.2
Jan 28	CALMET-6	10.7	8.0	9.7	1.4
Jan 28	RAMS-CALMET	4.7	19.7	52.9	2.9
Jan 28	CALMET-1	2.2	25.7	4.2	5.9
Jan 28	CALMET-3	15.3	8.9	3.9	0.9
Jan 29	OBSERVED	3.2	39.2	21.9	34.0
Jan 29	CALMET-6	8.8	49.5	70.0	11.1
Jan 29	RAMS-CALMET	2.5	33.6	25.3	0.7
Jan 29	CALMET-1	6.9	37.3	39.6	3.7
Jan 29	CALMET-3	39.8	71.6	39.0	5.0
Jan 30	OBSERVED	48.6	28.4	49.5	50.3
Jan 30	CALMET-6	46.7	50.4	40.0	5.1
Jan 30	RAMS-CALMET	19.6	78.3	44.3	13.5
Jan 30	CALMET-1	1.5	0.2	0.1	0.1
Jan 30	CALMET-3	3.5	2.2	1.4	1.8
Jan 31	OBSERVED	48.7	7.6	7.6	27.0
Jan 31	CALMET-6	51.0	28.4	2.1	4.6
Jan 31	RAMS-CALMET	24.5	96.6	26.3	14.2
Jan 31	CALMET-1	1.3	0.8	0.6	0.0
Jan 31	CALMET-3	1.3	1.0	1.2	0.0
Feb 1	OBSERVED	8.1	13.4	1.7	12.3
Feb 1	CALMET-6	7.7	13.7	2.5	2.4
Feb 1	RAMS-CALMET	3.7	13.2	3.6	4.4
Feb 1	CALMET-1	2.5	19.6	7.3	4.1
Feb 1	CALMET-3	6.7	7.5	1.6	0.2

Table B.1
Observed and modelled 24 hour concentrations ($\frac{\mu g}{m^3}$) at the 4 monitoring locations, January 28 to February 1.

DAY	MODEL	PLAZA	JAIL	CBC	GLADSTONE
Apr 13	OBSERVED	0.0	0.3	0.9	N/A
Apr 13	CALMET-6	0.0	0.3	1.0	0.0
Apr 13	RAMS-CALMET	0.0	0.3	1.1	0.0
Apr 13	CALMET-1	0.0	0.0	0.4	0.0
Apr 13	CALMET-3	0.0	0.0	0.0	0.0
Apr 14	OBSERVED	0.91	2.1	9.6	N/A
Apr 14	CALMET-6	12.6	54.3	70.1	1.7
Apr 14	RAMS-CALMET	0.3	6.3	2.8	2.0
Apr 14	CALMET-1	0.1	0.8	2.0	0.5
Apr 14	CALMET-3	0.3	0.8	1.3	0.1
Apr 15	OBSERVED	20.7	15.3	12.8	N/A
Apr 15	CALMET-6	27.4	96.7	34.9	4.9
Apr 15	RAMS-CALMET	10.1	57.5	38.2	7.3
Apr 15	CALMET-1	0.7	0.1	0.0	6.0
Apr 15	CALMET-3	2.8	0.2	0.0	5.7
Apr 16	OBSERVED	24.5	22.3	35.9	N/A
Apr 16	CALMET-6	43.5	59.0	34.4	3.1
Apr 16	RAMS-CALMET	9.9	22.3	15.0	2.8
Apr 16	CALMET-1	11.0	11.5	0.0	14.6
Apr 16	CALMET-3	28.3	12.4	0.1	10.0
Apr 17	OBSERVED	19.8	46.1	117.7	N/A
Apr 17	CALMET-6	11.4	83.9	56.2	40.9
Apr 17	RAMS-CALMET	5.4	9.4	12.6	3.3
Apr 17	CALMET-1	24.0	46.5	56.9	7.5
Apr 17	CALMET-3	36.7	128.2	98.4	18.0

Table B.2
Observed and modelled 24 hour concentrations ($\frac{\mu g}{m^3}$) at the 4 monitoring locations, April 13 to 17.

DAY	MODEL	PLAZA	JAIL	CBC	GLADSTONE
Jun 8	OBSERVED	0.8	0.1	5.3	N/A
Jun 8	CALMET-6	0.4	5.2	4.3	1.0
Jun 8	RAMS-CALMET	0.1	0.5	0.4	0.0
Jun 8	CALMET-1	1.4	6.5	4.7	0.2
Jun 8	CALMET-3	0.6	0.8	0.8	0.0
Jun 9	OBSERVED	1.7	1.7	7.2	N/A
Jun 9	CALMET-6	10.1	18.1	31.7	3.1
Jun 9	RAMS-CALMET	0.6	3.1	1.9	0.5
Jun 9	CALMET-1	0.1	3.2	6.2	0.1
Jun 9	CALMET-3	0.1	0.4	0.5	0.0
Jun 10	OBSERVED	1.3	0.8	13.7	N/A
Jun 10	CALMET-6	0.4	6.0	8.0	1.2
Jun 10	RAMS-CALMET	0.6	10.4	7.4	0.1
Jun 10	CALMET-1	6.8	15.3	11.9	3.4
Jun 10	CALMET-3	14.8	3.4	32.6	10.2
Jun 11	OBSERVED	13.0	2.7	7.0	N/A
Jun 11	CALMET-6	22.0	30.9	23.9	1.0
Jun 11	RAMS-CALMET	12.2	62.7	29.1	5.1
Jun 11	CALMET-1	5.4	14.4	9.2	2.9
Jun 11	CALMET-3	1.4	1.2	0.6	1.6
Jun 12	OBSERVED	15.4	15.7	56.3	N/A
Jun 12	CALMET-6	24.7	28.0	10.4	1.8
Jun 12	RAMS-CALMET	42.2	27.9	11.2	55.1
Jun 12	CALMET-1	15.7	11.3	4.5	0.4
Jun 12	CALMET-3	18.2	3.5	2.5	0.2

Table B.3

Observed and modelled 24 hour concentrations ($\frac{\mu g}{m^3}$) at the 4 monitoring locations, June 8 to 12.

APPENDIX C

C.7. RAMS Initialization File

```
!namelist
!############################ Change Log ##################################
! RAMS 4.3.0.0
!
!##########################################################################

 $MODEL_GRIDS

! Simulation title (64 chars)

   EXPNME   = 'Prince George Run, January 28 to February 2, 1999 (v4.3.0)',
   VTABCUST = 'standard',

   RUNTYPE  = 'INITIAL',    ! Type of run: MEMORY,    MAKESFC, MAKESST,
                            !              MAKEVFILE, INITIAL, HISTORY

   TIMEUNIT = 'h',          ! 'h','m','s' - Time units of TIMMAX, TIMSTR

   TIMMAX   = 132.,          ! Final time of simulation

!  Start of simulation or ISAN processing

   IMONTH1  = 01,           ! Month
   IDATE1   = 28,           ! Day
   IYEAR1   = 1999,         ! Year
   ITIME1   = 0000,         ! GMT of model TIME = 0.

! Grid specifications

   NGRIDS   = 3,            ! Number of grids to run

   NNXP     = 100,50,62,        ! Number of x gridpoints
   NNYP     = 100,50,62,        ! Number of y gridpoints
   NNZP     = 40,40,40,        ! Number of z gridpoints
   NZG      = 11,11,11,           ! Number of soil layers
   NZS      = 1,1,1,            ! Maximum number of snow layers

   NXTNEST  = 0,1,2,3,          ! Grid number which is the next coarser grid

! Coarse grid specifications

   IHTRAN   = 1,            ! 0-Cartesian, 1-Polar stereo
   DELTAX   = 16000.,
   DELTAY   = 16000.,       ! X and Y grid spacing

   DELTAZ   = 25.,         ! Z grid spacing (set to 0. to use ZZ)
   DZRAT    = 1.14,         ! Vertical grid stretch ratio
   DZMAX    = 1000.,        ! Maximum delta Z for vertical stretch

   ZZ       = 0.0,          ! Vertical levels if DELTAZ = 0
     30.0,      60.0,      90.0,     120.0,     150.0,
    180.0,     210.0,     240.0,     270.0,     300.0,
    330.0,     360.0,     390.0,     420.0,     450.0,
    480.0,     510.0,     540.0,     570.0,     600.0,
    630.0,     660.0,     690.0,     720.0,     750.0,
    780.0,     810.0,     840.0,     870.0,     900.0,
    930.0,     960.0,     990.0,    1020.0,    1050.0,
   1080.0,    1110.0,    1140.0,    1170.0,    1200.0,
   1230.0,    1260.0,    1290.0,    1320.0,    1350.0,
   1380.0,    1410.0,    1440.0,    1470.0,    1500.0,
   1533.0,    1569.3,    1609.2,    1653.2,    1701.5,
   1754.6,    1813.1,    1877.4,    1948.1,    2025.9,
   2111.5,    2205.7,    2309.3,

   DTLONG   = 25.,         ! Coarse grid long timestep
   NACOUST  = 4,4,4,            ! Small timestep ratio
   IDELTAT  = 2,           ! Timestep adjustment
                            !   =0 - constant timesteps
                            !   >0 - initial computation <0 - variable

                            ! Nest ratios between this grid and the next
                            !   coarser grid.
   NSTRATX  = 1,4,4,4,          ! x-direction
   NSTRATY  = 1,4,4,4,          ! y-direction
   NNDTRAT  = 1,5,5,5,          ! Time

   NESTZ1   = 0,            ! Contort coarser grids if negative
   NSTRATZ1 = 1,3,3,3,3,2,2,2,2,1,1,1,1,
   NESTZ2   = 0,            ! Contort coarser grids if negative
   NSTRATZ2 = 1,1,3,3,3,3,3,2,2,2,2,1,1,


   POLELAT  =  53.957,        ! Latitude of pole point
   POLELON  = -122.733,        ! Longitude of pole point

   CENTLAT =   53.957, 53.957,53.957,  ! Center lat/lon of grids, may or
   CENTLON =  -122.733,-122.733,-122.733,  !   may not be same as pole point.

                            ! Grid point on the next coarser
```

```
                          !   nest where the lower southwest
                          !   corner of this nest will start.
                          !   If NINEST or NJNEST = 0, use CENTLAT/LON
   NINEST   = 0,0,0,        ! i-point
   NJNEST   = 0,0,0,        ! j-point
   NKNEST   = 1,1,1,        ! k-point

   NNSTTOP  = 1,1,1,        ! Flag (0-no or 1-yes) if this
   NNSTBOT  = 1,1,1,        ! Nest goes the top or bottom of the
                          !   coarsest nest.

   GRIDU    = 0.,0.,0.,      ! u-component for moving grids
   GRIDV    = 0.,0.,0.,      ! v-component for moving grids
                          !   (still not working!)

 $END

 $MODEL_FILE_INFO

! Variable initialization input

   INITIAL  = 2,            ! Initial fields - 1=horiz.homogeneous,
                           !                  2=variable
   VARFPFX  = 'isan/is-v',     ! Varfile initialization file prefix
   VWAIT1   = 0.,           ! Wait between each VFILE check (s)
   VWAITTOT = 0.,           ! Total wait befor giving up on a VFILE (s)

   NUDLAT   = 5,            ! Number of points in lateral bnd region
   TNUDLAT  = 900.,         ! Nudging time scale(s) at lateral boundary
   TNUDCENT = 8000.,           ! Nudging time scale(s) in center of domain
   TNUDTOP  = 2000.,         ! Nudging time scale (s) at top of domain
   ZNUDTOP  = 10000.,       ! Nudging at top of domain above height(m)

! History file input

   TIMSTR   = 24.,           ! Time of history start (see TIMEUNIT)
   HFILIN   = 'hist/a-H-2000-07-30-180000.vfm',
                           ! Input history file name

! History/analysis file output

   IOUTPUT  = 1,            ! 0-no files, 1-save ASCII, 2-save binary
   HFILOUT  = 'hist/a',     ! History file prefix
   AFILOUT  = 'anal/a',     ! Analysis file prefix
   ICLOBBER = 1,            ! 0=stop if files exist, 1=overwite files
   IHISTDEL = 1,            ! 0=keep all hist files, 1=delete previous
   FRQHIS   = 43200.,       ! History file frequency
   FRQANL   = 7200.,       ! Analysis file frequency
   FRQLITE  = 0,        ! Analysis freq. for "lite" variables
                           !   = 0 : no lite files
   XLITE    = '/0:0/',      ! nums>0 are absolute grid indexes
   YLITE    = '/0:0/',      ! nums<0 count in from the domain edges
   ZLITE    = '/0:0/',      ! nums=0 are domain edges
   AVGTIM   = 0,        ! Averaging time for analysis variables
                           !   must be abs(AVGTIM) <= FRQANL
                           !   > 0 : averaging is centered at FRQANL
                           !   < 0 : averaging ends at FRQANL
                           !   = 0 : no averaged files
   FRQMEAN  = 10800.,       ! Analysis freq. for "averaged" variables
   FRQBOTH  = 3600.,        ! Analysis freq. for both "averaged" and
                           !   "lite" variables
   KWRITE   = 1,            ! 1-write,0-don't write scalar K's to anal.

! Printed output controls

   FRQPRT   = 21600.,       ! Printout frequency
   INITFLD  = 0,            ! Initial field print flag 0=no prnt,1=prnt

! Input topography variables

   SFCFILES = 'sfc/sfc',    ! File path and prefix for surface files.
   SSTFPFX  = 'sst/sst',    ! Path and prefix for sst files

   ITOPTFLG = 1,1,1,          ! 2 - Fill data in "rsurf"
   ISSTFLG  = 1,1,1,          ! 0 - Interpolate from coarser grid
   IVEGTFLG = 1,1,1,          ! 1 - Read from standard Lat/Lon data file
   ISOILFLG = 2,2,2,          ! Soil files not yet available: avoid isoilflg=1

   NOFILFLG = 2,2,2,          ! 2 - Fill data in "rsurf"
                           ! 0 - Interpolate from coarser grid

   IUPDSST  = 0,            ! 0 - No update of SST values during run
                           ! 1 - Update SST values during run

                           ! The following only apply for IxxxxFLG=1
   ITOPTFN  = '../data/topo30s/EL',
              '../data/topo30s/EL',
      '../data/topo30s/EL',
              '../data/topo30s/EL',
```

```
   ISSTFN   = '../data/sst/S',
              '../data/sst/S',
      '../data/sst/S',
              '../data/sst/S',
   IVEGTFN  = '../data/ogedata/GE',
              '../data/ogedata/GE',
      '../data/ogedata/GE',
              '../data/ogedata/GE',
   ISOILFN  = ' ',           ! Soil files not yet available

! Topography scheme

   ITOPSFLG = 1,1,1,           ! 0 = Average Orography
                             ! 1 = Silhouette Orography
                             ! 2 = Envelope Orography
                             ! 3 = Reflected Envelope Orography
   TOPTENH  = 1.,1.,1.,         ! For ITOPSFLG=1, Weighting of topo
                             !   silhouette averaging
                             ! For ITOPSFLG=2 or 3, Reflected Envelope
                             !   and Envelope Orography enhancement factor
   TOPTWVL  = 4.,4.,4.,         ! Topo wavelength cutoff in filter

! Surface Roughness scheme

   IZ0FLG   = 0,0,0,           ! 0 = Based of vege, bare soil and water surface
                             ! 1 = Subgrid scale orograhic roughness
   Z0MAX    = 2.,2.,         ! Max zo for IZ0FLG=1
   Z0FACT   = 0.005,         ! Subgrid scale orograhic roughness factor

! Microphysics collection tables

   MKCOLTAB = 0,             ! Make table: 0 = no, 1 = yes
   COLTABFN = '../data/ct2.0',
                             ! Filename to read or write

 $END

 $MODEL_OPTIONS

   NADDSC   = 0,             ! Number of additional scalar species

! Numerical schemes

   ICORFLG  = 1,             ! Coriolis flag/2D v-component  -  0 = off, 1 = on

   IBND     = 1,             ! Lateral boundary condition flags
   JBND     = 1,             !   1-Klemp/Wilhelmson, 2-Klemp/Lilly,
                             !   3-Orlanski,        4-cyclic
   CPHAS    = 20.,           ! Phase speed if IBND or JBND = 1
   LSFLG    = 0,             ! Large-scale gradient flag for variables other than
                             !   normal velocity:
                             !   0 = zero gradient inflow and outflow
                             !   1 = zero gradient inflow, radiative b.c. outflow
                             !   2 = constant inflow, radiative b.c. outflow
                             !   3 = constant inflow and outflow
   NFPT     = 0,             ! Rayleigh friction - number of points from the top
   DISTIM   = 60.,           !                   - dissipation time scale

! Radiation parameters

   ISWRTYP  = 1,             ! Shortwave radiation type
   ILWRTYP  = 1,             ! Longwave radiation type
                             !   0-none, 2-Mahrer/Pielke, 1-Chen
   RADFRQ   = 120.,         ! Freq. of radiation tendency update (s)
   LONRAD   = 1,             ! Longitudinal variation of shortwave
                             !   (0-no, 1-yes)

! Cumulus parameterization parameters

   NNQPARM  = 1,1,1,           ! Convective param. flag (0-off, 1-on)
   CONFRQ   = 1200.,         ! Frequency of conv param. updates (s)
   WCLDBS   = .001,          ! Vertical motion needed at cloud base for
                             !   to trigger convection

! Surface layer and soil parameterization

   NPATCH   = 3,             ! Number of patches per grid cell (min=2)

   NVEGPAT  = 2,             ! Number of patches per grid cell to be filled from
                             !  vegetation files (min of 1, max of NPATCH-1)

   ISFCL    = 0,             ! Surface layer/soil/veg model
                             !   0 - specified surface layer gradients
                             !   1 - soil/vegetation model

   NVGCON   = 3,             ! Vegetation type (see below)

   !   1 -- Crop/mixed farming         2 -- Short grass
   !   3 -- Evergreen needleleaf tree  4 -- Deciduous needleleaf tree
```

```
   !   5 -- Deciduous broadleaf tree   6 -- Evergreen broadleaf tree
   !   7 -- Tall grass                  8 -- Desert
   !   9 -- Tundra                     10 -- Irrigated crop
   !  11 -- Semi-desert                12 -- Ice cap/glacier
   !  13 -- Bog or marsh               14 -- Inland water
   !  15 -- Ocean                      16 -- Evergreen shrub
   !  17 -- Deciduous shrub            18 -- Mixed woodland

   PCTLCON  = 1.,            ! Constant land % if for all domain
   NSLCON   = 6,             ! Constant soil type if for all domain

   !   1 -- sand             2 -- loamy sand      3 -- sandy loam
   !   4 -- silt loam        5 -- loam            6 -- sandy clay loam
   !   7 -- silty clay loam  8 -- clay loam       9 -- sandy clay
   !  10 -- silty clay      11 -- clay           12 -- peat

   ZROUGH   = 1.0,           ! Constant roughness if for all domain
   ALBEDO   = .4,            ! Constant albedo if not running soil model
   SEATMP   = 280.,          ! Constant water surface temperature

   DTHCON   = 0.,            ! Constant sfc layer  temp grad for no soil
   DRTCON   = 0.,            ! Constant sfc layer moist grad for no soil

   SLZ      = -.50,-.40,-.30,-.25,-.20,-.16,-.12,-.09,-.06,-.03,-.01,
                             ! Soil grid levels

   SLMSTR   = 0.35,0.35,0.35,0.35,0.35,0.35,0.35,0.35,0.35,0.35,0.35,
                             ! Initial soil moisture

   STGOFF   = 5.,5.,5.,5.,3.5,2.,.5,-1.,-1.5,-1.8,-2.,
                             ! Initial soil temperature offset
                             !   from lowest atmospheric level

! Eddy diffusion coefficient parameters

   IDIFFK  = 1,1,1,            ! K flag:
                             !  1 - Horiz deform/Vert Mellor-Yamada
                             !  2 - Anisotropic deformormation
                             !      (horiz & vert differ)
                             !  3 - Isotropic deformation
                             !      (horiz and vert same)
                             !  4 - Deardorff TKE (horiz and vert same)
   IHORGRAD = 1,             !  1 - horiz grad frm decomposed sigma grad
                             !  2 - true horizontal gradient.
                             !      Non-conserving, but allows small DZ
   CSX     = .2,.2,.2,          ! Deformation horiz. K's coefficient
   CSZ     = .2,.2,.2,          ! Deformation vert. K's coefficient
   XKHKM   = 3.,3.,3.,          ! Ratio of horiz K_h to K_m for deformation
   ZKHKM   = 3.,3.,3.,          ! Ratio of vert K_h to K_m for deformation
   AKMIN   = 1.,1.,1.,          ! Ratio of minimum horizontal eddy
                             !    viscosity coefficientto typical value
                             !    from deformation K

! Microphysics

   LEVEL   = 3,              ! Moisture complexity level
   ICCNFLG = 0,              ! Flag for CCN and IF
   IFNFLG  = 0,              !   0-constant,1-vertical profile,2-prognosed

   ICLOUD  = 4,              ! Microphysics flags
   IRAIN   = 2,              !-------------------
   IPRIS   = 5,              !   1 - diagnostic concen.
   ISNOW   = 2,              !   2 - specified mean diameter
   IAGGR   = 2,              !   3 - specified y-intercept
   IGRAUP  = 2,              !   4 - specified concentration
   IHAIL   = 2,              !   5 - prognostic concentration

   CPARM   = .3e9,           !  Microphysics parameters
   RPARM   = 1e-3,           !-------------------------
   PPARM   = 0.,             !  Characteristic diameter, # concentration
   SPARM   = 1e-3,           !     or y-intercept
   APARM   = 1e-3,
   GPARM   = 1e-3,
   HPARM   = 3e-3,

   GNU     = 2.,2.,2.,2.,2.,2.,2., ! Gamma shape parms for
                                   ! cld rain pris snow aggr graup hail

 $END

 $MODEL_SOUND

!-----------------------------------
! Sounding specification
!-----------------------------------

! Flags for how sounding is specified

   IPSFLG   = 1,             ! Specifies what is in PS array
```

```
                         !   0-pressure(mb) 1-heights(m)
                         !   PS(1)=sfc press(mb)

   ITSFLG   = 0,         !  Specifies what is in TS array
                         !  0-temp(C) 1-temp(K) 2-pot. temp(K)

   IRTSFLG  = 3,         ! Specifies what is in RTS array
                         !   0-dew pnt.(C) 1-dew pnt.(K)
                         !   2-mix rat(g/kg)
                         !   3-relative humidity in %,
                         !   4-dew pnt depression(K)

   IUSFLG   = 0,         ! Specifies what is in US and VS arrays
                         !   0-u,v component(m/s)
                         !   1-umoms-direction, vmoms-speed

   HS       = 0.,

   PS       = 1010.,1000.,2000.,3000.,4000.,6000.,8000.,11000.,15000.,20000.,
              25000.,

   TS       = 25.,18.5,12.,4.5,-11.,-24.,-37.,-56.5,-56.5,-56.5,-56.5,

   RTS      = 70.,70.,70.,70.,20.,20.,20.,20.,10.,10.,10.,

   US       = 10.,10.,10.,10.,10.,10.,10.,10.,10.,10.,10.,

   VS       = 0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,

 $END

 $MODEL_PRINT

!-----------------------------------
! Specifies the fields to be printed during the simulation
!-----------------------------------

   NPLT     = 4,         ! Number of fields printed at each time
                         !   for various cross-sections (limit of 50)

   IPLFLD   = 'UP','VP','WP','THETA','RELHUM','TOTPRE',
                         ! Field names - see table below

!   PLFMT(1)  = '0PF7.3',   ! Format spec. if default is unacceptable

   IXSCTN    = 3,3,3,3,
                         ! Cross-section type (1=XZ, 2=YZ, 3=XY)

   ISBVAL    = 10,10,10,10,
                         ! Grid-point slab value for third direction

  ! The following variables can also be set in the  namelist:  IAA,
  ! IAB, JOA, JOB, NAAVG, NOAVG, PLTIT, PLCONLO, PLCONHI, and PLCONIN.

!     'UP'    - UP(M/S)     'RC'   - RC(G/KG)    'PCPT' - TOTPRE
!     'VP'    - VP(M/S)     'RR'   - RR(G/KG)    'TKE'  - TKE
!     'WP'    - WP(CM/S)    'RP'   - RP(G/KG)    'HSCL' - HL(M)
!     'PP'   - PRS(MB)      'RA'   - RA(G/KG)    'VSCL' - VL(M)
!     'THP'  - THP(K)
!     'THETA'- THETA(K)     'RL'   - RL(G/KG)    'TG'   - TG (K)
!     'THVP' - THV(K)       'RI'   - RI(G/KG)    'SLM'  - SLM (PCT)
!     'TV'   - TV(K)        'RCOND'- RD(G/KG)    'CONPR'- CON RATE
!     'RT'   - RT(G/KG)     'CP'   - NPRIS       'CONP' - CON PCP
!     'RV'   - RV(G/KG)     'RTP'  - RT(G/KG)    'CONH' - CON HEAT
!                                                'CONM' - CON MOIS
!     'THIL' - Theta-il (K) 'TEMP' - temperature (K)
!     'TVP'  - Tv (K)       'THV'  - Theta-v     (K)
!     'RELHUM'-relative humidity (%)             'SPEED'- wind speed (m/s)
!     'FTHRD'- radiative flux convergence (??)
!     'MICRO'- GASPRC
!     'Z0'   - Z0 (M)       'ZI'   - ZI (M)      'ZMAT' - ZMAT (M)
!     'USTARL'-USTARL(M/S)  'USTARW'-USTARW(M/S) 'TSTARL'-TSTARL (K)
!     'TSTARW'-TSTARW(K)    'RSTARL'-RSTARL(G/G) 'RSTARW'-RSTARW(G/G)
!     'UW'   - UW  (M*M/S*S)                     'VW'   - VW (M*M/S*S)
!     'WFZ'  - WFZ (M*M/S*S)                     'TFZ'  - TFZ (K*M/S)
!     'QFZ'  - QFZ (G*M/G*S)                     'RLONG'- RLONG
!     'RSHORT'-RSHORT

 $END

 $ISAN_CONTROL

!-----------------------------------
! Isentropic control
!-----------------------------------

   ISZSTAGE = 1,         ! Main switches for isentropic-sigz
   IVRSTAGE = 1,         !   "varfile" processing
```

```
   ISAN_INC = 0600,         ! ISAN processing increment (hhmm)
                            !   range controlled by TIMMAX,
                            !   IYEAR1,...,ITIME1

   GUESS1ST = 'PRESS',      ! Type of first guess input- 'PRESS', 'RAMS'

   I1ST_FLG = 1,            ! What to do if first guess file should be used,
                            !   but does not exist.
                            !     1 = I know it may not be there,
                            !         skip this data time
                            !     2 = I screwed up, stop the run
                            !     3 = interpolate first guess file from nearest
                            !         surrounding times, stop if unable
                            !         (not yet available)

   IUPA_FLG = 3,            ! UPA-upper air, SFC-surface
   ISFC_FLG = 3,            ! What to do if other data files should be used,
                            !   but does not exist.
                            !     1 = I know it may not be there,
                            !         skip this data time
                            !     2 = I screwed up, stop the run
                            !     3 = Try to continue processing anyway

! Input data file prefixes

   IAPR    = '../ncep/jan99/dp-p', ! Input press level dataset
   IARAWI  = 'NO/ncep/jan99/dp-r', ! Archived rawindsonde file name
   IASRFCE = 'NO/data/sfc/jan99/dp-s', ! Archived surface obs file name

! File names and dispose flags

   VARPFX    = './isan/is-v',  ! isan file names prefix
   IOFLGISZ  = 0,           ! Isen-sigz file flag: 0 = no write, 1 = write
   IOFLGVAR  = 1,           ! Var file flag:       0 = no write, 1 = write

 $END

 $ISAN_ISENTROPIC

!-----------------------------------
! Isentropic and sigma-z processing
!-----------------------------------

!-----------------------------------
! Specify isentropic levels
!-----------------------------------

   NISN     = 56,           ! Number of isentropic levels
   LEVTH    = 254,255,256,257,258,259,260,261,262,263,
              264,265,266,267,268,269,270,271,272,273,274,275,276,278,280,282,
              284,286,288,290,292,294,296,298,300,303,306,309,312,315,318,
              321,324,327,330,335,340,345,350,355,360,380,400,420,440,460,

!-----------------------------------
! Analyzed grid information:
!-----------------------------------

   NIGRIDS  = 3,            ! Number of RAMS grids to analyze

   TOPSIGZ  = 20000.,       ! Sigma-z coordinates to about this height

   HYBBOT   = 4000.,        ! Bottom (m) of blended sigma-z/isentropic
                            !   layer in varfiles
   HYBTOP   = 6000.,        ! Top (m) of blended sigma-z/isentropic layr

   SFCINF   = 100.,        ! Vert influence of sfc observation analysis

   SIGZWT   = 1.,           ! Weight for sigma-z data in varfile:
                            !   0. = no sigz data,
                            !   1. = full weight from surface to HYBBOT

   NFEEDVAR = 1,            ! 1 = feed back nested grid varfile, 0 = not

!-----------------------------------
! Observation number limits:
!-----------------------------------

   MAXSTA   = 500,          ! maximum number of rawindsondes
                            !    (archived + special)
   MAXSFC   = 5000,         ! maximum number of surface observations

   NONLYS   = 0,            ! Number of stations only to be used
   IDONLYS  = '76458',      ! Station IDs used

   NOTSTA   = 0,            ! Number of stations to be excluded
   NOTID    = 'r76458',     ! Station IDs to be excluded
                            !   Prefix with 'r' for rawindsonde,
                            !               's' for surface
```

```
   IOBSWIN  = 7200,         ! Observation acceptance time window
                            !   Obs are accepted at the analysis time T if
                            !   for IOBSWIN > 0: T-IOBSWIN < obs_time < T+IOBSWIN
                            !   for IOBSWIN = 0: T = obs_time
                            !   for IOBSWIN < 0: T-|IOBSWIN| < obs_time

   STASEP   = .0001,           ! Minimum sfc station separation in degrees.
                            !   Any surface obs within this distance
                            !   of another obs will be thrown out
                            !   unless it has less missing data,
                            !   in which case the other obs will be
                            !   thrown out.

   ISTAPLT  = 0,            ! If ISTAPLT = 1, soundings are plotted;
   ISTAREP  = 0,            ! If ISTAREP = 1, soundings are listed;
                            !   no objective analysis is done.
                            ! If ISTAREP/ISTAPLT = 0, normal processing
                            !   is done

   IGRIDFL  = 4,            ! Grid flag=0 if no grid point, only obs
                            !           1 if all grid point data and obs
                            !           2 if partial grid point and obs
                            !           3 if only grid data
                            !           4 all data... fast

   GRIDWT   = .001,.001,      ! Relative weight for the gridded press data
                            !   compared to the observational data in
                            !   the objective analysis

   GOBSEP   = 5.,           ! Grid-observation separation (degrees)
   GOBRAD   = 5.,           ! Grid-obs proximity radius (degrees)

   WVLNTH   = 1200.,900.,600.,   ! Used in S. Barnes objective analysis.
                            !   Wavelength in km to be retained to the
                            !   RESPON % from the data to the upper air
                            !   grids.
   SWVLNTH  = 750.,300.,150.,    ! Wavelength for surface objective analysis

   RESPON   = .90,.9,.9,       ! Percentage of amplitude to be retained.

 $END

!-----------------------------------
! Graphical processing
!-----------------------------------

 $ISAN_GRAPH

! Main switches for plotting

   IPLTPRS  = 0,            ! Pressure coordinate horizontal plots
   IPLTISN  = 0,            ! Isentropic coordinate horizontal plots
   IPLTSIG  = 0,            ! Sigma-z coordinate horizontal plots
   IPLTSTA  = 0,            ! Isentropic coordinate "station" plots

!-----------------------------------
! Pressure plotting information
!-----------------------------------

   ILFT1I   = 0,            ! Left boundary window
   IRGT1I   = 18,           ! Right boundary window
   IBOT1J   = 3,            ! Bottom boundary window
   ITOP1J   = 13,           ! Top boundary window
                            !  Window defaults to entire domain if one equals 0.

   NPLEV    = 2,            ! Number of pressure levels to plot
   IPLEV    = 1000,500,
                            ! Levels to be plotted
   NFLDU1   = 4,            ! Number of fields to be plotted
   IFLDU1   = 'U','THETA','GEO','RELHUM', ! Field names
   CONU1    = 0.,0.,0.,0.,  ! Field contour increment
   IVELU1   = 2,0,0,0,      ! Velocity vector flag

!-----------------------------------
! Isentropic plotting information
!-----------------------------------

   ILFT3I   = 0,            ! Left boundary window
   IRGT3I   = 18,           ! Right boundary window
   IBOT3J   = 3,            ! Bottom boundary window
   ITOP3J   = 13,           ! Top boundary window
                            !  Window defaults to entire domain if one equals 0.

! Upper air plots:

   IUP3BEG  = 320,          ! Starting isentropic level for plotting
   IUP3END  = 380,          ! Ending isentropic level
   IUP3INC  = 60,           ! Level increment
```

```
   NFLDU3   = 5,            ! Number of fields to be plotted
   IFLDU3   = 'U','V','PRESS','GEO','RELHUM', ! Field names
   CONU3    = 0.,0.,        ! Field contour increment
   IVELU3   = 1,0,          ! Velocity vector flag


!-----------------------------------
! Surface plotting information
!-----------------------------------

! Uses isentropic plotting window info

   NFLDS3   = 5,            ! Number of surface fields to plot
   IFLDS3   = 'U','V','PRESS','GEO','RELHUM',  ! Field names
   CONS3    = 0.,0.,0.,0.,0.,  ! Field contour increment
   IVELS3   = 1,0,0,0,0,    ! Velocity vector flag

!-----------------------------------
! Sigma-z plotting information
!-----------------------------------

! Uses isentropic plotting window info

   ISZBEG   = 2,            ! Starting sigma-z level for plotting
   ISZEND   = 8,            ! Ending sigma-z level
   ISZINC   = 6,            ! Level increment

   NFLDSZ   = 5,            ! Number of fields to be plotted
   IFLDSZ   = 'U','V','PRESS','THETA','RELHUM', ! Field names
   CONSZ    = 0.,0.,        ! Field contour increment
   IVELSZ   = 1,0,          ! Velocity vector flag

!-----------------------------------
! "Station" plotting information
!-----------------------------------

   NPLTRAW  = 25,           ! Approximate number of raw rawinsonde plots
                            !   per frame. 0 turns off plotting.

   NSTIS3   = 2,            ! Number of station surface plots
   ISTIS3   = 'PRESS','RELHUM','MIXRAT',  ! Field names

!-----------------------------------
! Cross-section plotting information
!-----------------------------------

   NCROSS3  = 0,            ! Number of cross section slabs
   ICRTYP3  = 2,1,          ! Type of slab: 1=E-W, 2=N-S
   ICRA3    = 1,1,          ! Left window
   ICRB3    = 35,43,        ! Right window
   ICRL3    = 22,25,        ! Cross section location
   NCRFLD3  = 3,            ! Number of plots on each cross section
   ICRFLD3  = 'MIXRAT','RELHUM','THETAE',  ! field names
   THCON3   = 5.,5.,5.,     ! Contour interval of isentropes
   ACON3    = 0.,0.,0.,     ! Contour interval of other field

 $END

 !-----------------------------------
 !   Field values for graphical stage
 !-----------------------------------
 !
 !     Pressure        Isentropic    Station       Sigma-z
 !---------------------------------------------------------------------
 !     U               U             U             U
 !     V               V             V             V
 !     TEMP            PRESS         PRESS         PRESS
 !     GEO             GEO           TEMP          THETA
 !     RELHUM          RELHUM        RELHUM        RELHUM
 !     MIXRAT          MIXRAT        MIXRAT
 !     THETA           THETA
 !     SPEED           SPEED
 !     ENERGY          ENERGY
 !     THETAE          THETAE
 !     SPRESS          SPRESS
 !
```

C.8. CALMET Initialization File

```
CALMET RUN USING RAMS GENERATED SURFACE AND UPPER AIR STATIONS
JANUARY 28 - FEBRUARY 1

--------------- Run title (3 lines) -----------------------------------------

                    CALMET MODEL CONTROL FILE
                    -------------------------

-----------------------------------------------------------------------------

INPUT GROUP: 0 -- Input and Output File Names


Subgroup (a)
------------
Default Name  Type          File Name
------------  ----          ---------
GEO.DAT       input    ! GEODAT=C:\CALPUFF\CMETIN~1\GEO600.DAT       !
SURF.DAT      input    ! SRFDAT=C:\CALDATA\CMETIN\SFC\RAMS\J99RSFC6.DAT      !
CLOUD.DAT     input    * CLDDAT=            *
PRECIP.DAT    input    * PRCDAT=            *
MM4.DAT       input    * MM4DAT=            *
WT.DAT        input    * WTDAT=             *

CALMET.LST    output   ! METLST=C:\CALFINAL\CMETOUT\JAN\JAN\JANL.LST     !
CALMET.DAT    output   ! METDAT=C:\CALFINAL\CMETOUT\JAN\JAN\JANL.DAT    !
PACOUT.DAT    output   * PACDAT=            *

All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
         T = lower case      ! LCFILES = T !
         F = UPPER CASE

NUMBER OF UPPER AIR & OVERWATER STATIONS:

    Number of upper air stations (NUSTA)  No default     ! NUSTA =  1  !
    Number of overwater met stations
                             (NOWSTA) No default     ! NOWSTA =  0  !

                       !END!
-------------------------------------------------------------------------------
Subgroup (b)
---------------------------------
Upper air files (one per station)
---------------------------------
Default Name  Type       File Name
------------  ----       ---------
UP1.DAT       input     1  ! UPDAT=C:\CALDATA\CMETIN\UPPER\UPJAN99.DAT!    !END!
-------------------------------------------------------------------------------
Subgroup (c)
-----------------------------------------
Overwater station files (one per station)
-----------------------------------------
Default Name  Type       File Name
------------  ----       ---------
-------------------------------------------------------------------------------
Subgroup (d)
----------------
Other file names
----------------

Default Name  Type       File Name
------------  ----       ---------
DIAG.DAT      input      * DIADAT=                  *
PROG.DAT      input      * PRGDAT=                  *

TEST.PRT      output     ! TSTPRT= C:\CALPUFF\CMETOU~1\WINDSJ3.PRT!
TEST.OUT      output     * TSTOUT=                  *
TEST.KIN      output     * TSTKIN=                  *
TEST.FRD      output     * TSTFRD=                  *
TEST.SLP      output     * TSTSLP=                  *

-------------------------------------------------------------------------------
NOTES: (1) File/path names can be up to 70 characters in length
       (2) Subgroups (a) and (d) must have ONE 'END' (surround by
           delimiters) at the end of the group
       (3) Subgroups (b) and (c) must have an 'END' (surround by
           delimiters) at the end of EACH LINE

                         !END!


-------------------------------------------------------------------------------

INPUT GROUP: 1 -- General run control parameters
--------------

     Starting date:   Year (IBYR) -- No default       ! IBYR=  1999  !
```

```
                     Month (IBMO) -- No default       ! IBMO=  1  !
                       Day (IBDY) -- No default       ! IBDY=  28  !
                      Hour (IBHR) -- No default       ! IBHR=  0  !

     Base time zone        (IBTZ) -- No default       ! IBTZ=  8  !
        PST = 08, MST = 07
        CST = 06, EST = 05

     Length of run (hours) (IRLG) -- No default       ! IRLG=  120  !

     Run type            (IRTYPE) -- Default: 1       ! IRTYPE=  1  !

        0 = Computes wind fields only
        1 = Computes wind fields and micrometeorological variables
            (u*, w*, L, zi, etc.)
        (IRTYPE must be 1 to run CALPUFF or CALGRID)

     Compute special data fields required
     by CALGRID (i.e., 3-D fields of W wind
     components and temperature)
     in additional to regular           Default: T    ! LCALGRD = T !
     fields ? (LCALGRD)
     (LCALGRD must be T to run CALGRID)

      Flag to stop run after
      SETUP phase (ITEST)            Default: 2       ! ITEST=  2   !
      (Used to allow checking
      of the model inputs, files, etc.)
      ITEST = 1 - STOPS program after SETUP phase
      ITEST = 2 - Continues with execution of
                  COMPUTATIONAL phase after SETUP

!END!

-------------------------------------------------------------------------------

INPUT GROUP: 2 -- Grid control parameters
--------------

     HORIZONTAL GRID DEFINITION:

            No. X grid cells (NX)      No default     ! NX =   49  !
            No. Y grid cells (NY)      No default     ! NY =   49  !

     GRID SPACING (DGRIDKM)            No default     ! DGRIDKM = 0.5 !
                                       Units: km

     REFERENCE COORDINATES
     of SOUTHWEST corner of grid cell (1,1)

        X coordinate (XORIGKM)         No default     ! XORIGKM = 505.000 !
        Y coordinate (YORIGKM)         No default     ! YORIGKM = 5966.000 !
                                       Units: km
        Latitude  (XLAT0)              No default     ! XLAT0 = 53.840 !
        Longitude (XLON0)              No default     ! XLON0 = 122.930 !

     UTM ZONE (IUTMZN)                 Default: 0     ! IUTMZN =  10  !

     LAMBERT CONFORMAL PARAMETERS

     Rotate input winds from true north to
     map north using a Lambert conformal
     projection? (LLCONF)              Default: F     ! LLCONF = F !

     Latitude of 1st standard parallel   Default: 30.   ! XLAT1 = 30.000 !
     Latitude of 2nd standard parallel   Default: 60.   ! XLAT2 = 60.000 !
     (XLAT1 and XLAT2; + in NH, - in SH)

        Longitude (RLON0)                Default = 90.  ! RLON0 = 90.000 !
        (used only if LLCONF = T)
        (Positive = W. Hemisphere;
         Negative = E. Hemisphere)
        Origin Latitude (RLAT0)          Default = 40.  ! RLAT0 = 40.000 !
        (used only if IPROG > 2)
        (Positive = N. Hemisphere;
         Negative = S. Hemisphere)

     Vertical grid definition:

        No. of vertical layers (NZ)    No default     ! NZ =  8  !

        Cell face heights in arbitrary
        vertical grid (ZFACE(NZ+1))    No defaults
                                       Units: m
        ! ZFACE = 0.,20.,50.,100.,250.,500.,1000.,1500.,3500. !

!END!
```

```
--------------------------------------------------------------------------------

INPUT GROUP: 3 -- Output Options
--------------


    DISK OUTPUT OPTION

       Save met. fields in an unformatted
       output file ?             (LSAVE)  Default: T     ! LSAVE = T !
       (F = Do not save, T = Save)

       Type of unformatted output file:
       (IFORMO)                           Default: 1    ! IFORMO =  1  !

            1 = CALPUFF/CALGRID type file (CALMET.DAT)
            2 = MESOPUFF-II type file     (PACOUT.DAT)


    LINE PRINTER OUTPUT OPTIONS:

       Print met. fields ?  (LPRINT)       Default: F     ! LPRINT = F !
       (F = Do not print, T = Print)
       (NOTE: parameters below control which
              met. variables are printed)

       Print interval
       (IPRINF) in hours                  Default: 1     ! IPRINF =  6  !
       (Meteorological fields are printed
        every  6  hours)


       Specify which layers of U, V wind component
       to print (IUVOUT(NZ)) -- NOTE: NZ values must be entered
       (0=Do not print, 1=Print)
       (used only if LPRINT=T)        Defaults: NZ*0
       ! IUVOUT =  1 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0  !
       -----------------------


       Specify which levels of the W wind component to print
       (NOTE: W defined at TOP cell face --  8  values)
       (IWOUT(NZ)) -- NOTE: NZ values must be entered
       (0=Do not print, 1=Print)
       (used only if LPRINT=T & LCALGRD=T)
       -----------------------------------
                                           Defaults: NZ*0
        ! IWOUT =  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0  !


       Specify which levels of the 3-D temperature field to print
       (ITOUT(NZ)) -- NOTE: NZ values must be entered
       (0=Do not print, 1=Print)
       (used only if LPRINT=T & LCALGRD=T)
       -----------------------------------
                                           Defaults: NZ*0
        ! ITOUT =  1 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0  !

       Specify which meteorological fields
       to print
       (used only if LPRINT=T)            Defaults: 0 (all variables)
       -----------------------


         Variable            Print ?
                         (0 = do not print,
                          1 = print)
         --------        ------------------

      !  STABILITY  =           1           ! - PGT stability class
      !  USTAR      =           1           ! - Friction velocity
      !  MONIN      =           1           ! - Monin-Obukhov length
      !  MIXHT      =           1           ! - Mixing height
      !  WSTAR      =           1           ! - Convective velocity scale
      !  PRECIP     =           1           ! - Precipitation rate
      !  SENSHEAT   =           0           ! - Sensible heat flux
      !  CONVZI     =           0           ! - Convective mixing ht.


       Testing and debug print options for micrometeorological module

          Print input meteorological data and
          internal variables (LDB)        Default: F       ! LDB = F !
          (F = Do not print, T = print)
          (NOTE: this option produces large amounts of output)

          First time step for which debug data
          are printed (NN1)               Default: 1       ! NN1 =  1  !
```

```
          Last time step for which debug data
          are printed (NN2)                Default: 1       ! NN2 =  1  !


       Testing and debug print options for wind field module
       (all of the following print options control output to
        wind field module's output files: TEST.PRT, TEST.OUT,
        TEST.KIN, TEST.FRD, and TEST.SLP)

          Control variable for writing the test/debug
          wind fields to disk files (IOUTD)
          (0=Do not write, 1=write)        Default: 0       ! IOUTD =  0  !

          Number of levels, starting at the surface,
          to print (NZPRN2)                Default: 1       ! NZPRN2 =  1  !

          Print the INTERPOLATED wind components ?
          (IPR0) (0=no, 1=yes)             Default: 0       !  IPR0 =  0  !

          Print the TERRAIN ADJUSTED surface wind
          components ?
          (IPR1) (0=no, 1=yes)             Default: 0       !  IPR1 =  0  !

          Print the SMOOTHED wind components and
          the INITIAL DIVERGENCE fields ?
          (IPR2) (0=no, 1=yes)             Default: 0       !  IPR2 =  0  !

          Print the FINAL wind speed and direction
          fields ?
          (IPR3) (0=no, 1=yes)             Default: 0       !  IPR3 =  1  !

          Print the FINAL DIVERGENCE fields ?
          (IPR4) (0=no, 1=yes)             Default: 0       !  IPR4 =  0  !

          Print the winds after KINEMATIC effects
          are added ?
          (IPR5) (0=no, 1=yes)             Default: 0       !  IPR5 =  0  !

          Print the winds after the FROUDE NUMBER
          adjustment is made ?
          (IPR6) (0=no, 1=yes)             Default: 0       !  IPR6 =  0  !

          Print the winds after SLOPE FLOWS
          are added ?
          (IPR7) (0=no, 1=yes)             Default: 0       !  IPR7 =  0  !

          Print the FINAL wind field components ?
          (IPR8) (0=no, 1=yes)             Default: 0       !  IPR8 =  0  !

!END!

          (IPR8) (0=no, 1=yes)             Default: 0       !  IPR8 =  0  !

!END!



-------------------------------------------------------------------------------

INPUT GROUP: 4 -- Meteorological data options
--------------


    NUMBER OF SURFACE & PRECIP. METEOROLOGICAL STATIONS

       Number of surface stations   (NSSTA)  No default     ! NSSTA =  7  !
       Number of precipitation stations
                                    (NPSTA)  No default     ! NPSTA =  0  !

    CLOUD DATA OPTIONS
       Griddid cloud fields:
                                   (ICLOUD)  Default: 0     ! ICLOUD =  0  !
       ICLOUD = 0 - Gridded clouds not used
       ICLOUD = 1 - Gridded CLOUD.DAT generated as OUTPUT
       ICLOUD = 2 - Gridded CLOUD.DAT read as INPUT

    FILE FORMATS

       Surface meteorological data file format
                                   (IFORMS)  Default: 2     ! IFORMS =  2  !
       (1 = unformatted (e.g., SMERGE output))
       (2 = formatted   (free-formatted user input))

       Precipitation data file format
                                   (IFORMP)  Default: 2     ! IFORMP =  2  !
       (1 = unformatted (e.g., PMERGE output))
       (2 = formatted   (free-formatted user input))

       Cloud data file format
```

```
                            (IFORMC)  Default: 2     ! IFORMC =  1  !
       (1 = unformatted - CALMET unformatted output)
       (2 = formatted   - free-formatted CALMET output or user input)

!END!


--------------------------------------------------------------------------------

INPUT GROUP: 5 -- Wind Field Options and Parameters
--------------


    WIND FIELD MODEL OPTIONS
       Model selection variable (IWFCOD)     Default: 1      ! IWFCOD =  1  !
          0 = Objective analysis only
          1 = Diagnostic wind module

       Compute Froude number adjustment
       effects ? (IFRADJ)                    Default: 1      ! IFRADJ =  1  !
       (0 = NO, 1 = YES)

       Compute kinematic effects ? (IKINE)   Default: 0      ! IKINE  =  0  !
       (0 = NO, 1 = YES)

       Use O'Brien procedure for adjustment
       of the vertical velocity ? (IOBR)     Default: 0      ! IOBR =  0  !
       (0 = NO, 1 = YES)

       Compute slope flow effects ? (ISLOPE) Default: 1      ! ISLOPE  =  1  !
       (0 = NO, 1 = YES)

       Extrapolate surface wind observations
       to upper layers ? (IEXTRP)            Default: -4     ! IEXTRP = -4  !
       (1 = no extrapolation is done,
        2 = power law extrapolation used,
        3 = user input multiplicative factors
            for layers 2 - NZ used (see FEXTRP array)
        4 = similarity theory used
        -1, -2, -3, -4 = same as above except layer 1 data
            at upper air stations are ignored

       Extrapolate surface winds even
       if calm? (ICALM)                      Default: 0      ! ICALM  =  0  !
       (0 = NO, 1 = YES)

       Layer-dependent biases modifying the weights of
       surface and upper air stations (BIAS(NZ))
         -1<=BIAS<=1
       Negative BIAS reduces the weight of upper air stations
         (e.g. BIAS=-0.1 reduces the weight of upper air stations
       by 10%; BIAS= -1, reduces their weight by 100 %)
       Positive BIAS reduces the weight of surface stations
         (e.g. BIAS= 0.2 reduces the weight of surface stations
       by 20%; BIAS=1 reduces their weight by 100%)
       Zero BIAS leaves weights unchanged (1/R**2 interpolation)
       Default: NZ*0
                               ! BIAS = -1 , -1 , -1 , -.5 ,  0 ,  0 ,  0 ,  0  !

       Minimum distance from nearest upper air station
       to surface station for which extrapolation
       of surface winds at surface station will be allowed
       (RMIN2: Set to -1 for IEXTRP = 4 or other situations
        where all surface stations should be extrapolated)
                                              Default: 4.    ! RMIN2 = 4.0 !

       Use gridded prognostic wind field model
       output fields as input to the diagnostic
       wind field model (IPROG)              Default: 0      ! IPROG =  0  !
       (0 = No, [IWFCOD = 0 or 1]
        1 = Yes, use CSUMM prog. winds as Step 1 field, [IWFCOD = 0]
        2 = Yes, use CSUMM prog. winds as initial guess field [IWFCOD = 1]
        3 = Yes, use winds from MM4.DAT file as Step 1 field [IWFCOD = 0]
        4 = Yes, use winds from MM4.DAT file as initial guess field [IWFCOD = 1]
        5 = Yes, use winds from MM4.DAT file as observations [IWFCOD = 1]
        13 = Yes, use winds from MM5.DAT file as Step 1 field [IWFCOD = 0]
        14 = Yes, use winds from MM5.DAT file as initial guess field [IWFCOD = 1]
        15 = Yes, use winds from MM5.DAT file as observations [IWFCOD = 1]

    RADIUS OF INFLUENCE PARAMETERS

       Use varying radius of influence       Default: F      ! LVARY =  F!
       (if no stations are found within RMAX1,RMAX2,
        or RMAX3, then the closest station will be used)

       Maximum radius of influence over land
       in the surface layer (RMAX1)          No default      ! RMAX1 = 15. !
                                             Units: km
       Maximum radius of influence over land
```

```
      aloft (RMAX2)                       No default      ! RMAX2 = 5. !
                                          Units: km
      Maximum radius of influence over water
      (RMAX3)                             No default      ! RMAX3 = 10. !
                                          Units: km


   OTHER WIND FIELD INPUT PARAMETERS

      Minimum radius of influence used in
      the wind field interpolation (RMIN)   Default: 0.1    ! RMIN = 0.1 !
                                          Units: km
      Radius of influence of terrain
      features (TERRAD)                   No default      ! TERRAD = 10. !

                                          Units: km
      Relative weighting of the first
      guess field and observations in the
      SURFACE layer (R1)                  No default      ! R1 = 1. !
      (R1 is the distance from an         Units: km
      observational station at which the
      observation and first guess field are
      equally weighted)

      Relative weighting of the first
      guess field and observations in the
      layers ALOFT (R2)                   No default      ! R2 = 1. !
      (R2 is applied in the upper layers  Units: km
      in the same manner as R1 is used in
      the surface layer).

      Relative weighting parameter of the
      prognostic wind field data (RPROG)  No default      ! RPROG = 0. !
      (Used only if IPROG = 1)            Units: km
      ------------------------

      Maximum acceptable divergence in the
      divergence minimization procedure
      (DIVLIM)                            Default: 5.E-6  ! DIVLIM= 5.0E-06 !

      Maximum number of iterations in the
      divergence min. procedure (NITER)   Default: 50     ! NITER =  50  !

      Number of passes in the smoothing
      procedure (NSMTH(NZ))
      NOTE: NZ values must be entered
           Default: 2,(mxnz-1)*4 ! NSMTH =
2 ,  4 ,  4 ,  4 ,  4 ,  4 ,  4 ,  4  !

      Maximum number of stations used in
      each layer for the interpolation of
      data to a grid point (NINTR2(NZ))
      NOTE: NZ values must be entered     Default: 99.    ! NINTR2 =
99 ,  99 ,  99 ,  99 ,  99 ,  99 ,  99 ,  99  !

      Critical Froude number (CRITFN)     Default: 1.0    ! CRITFN = 1. !

      Empirical factor controlling the
      influence of kinematic effects
      (ALPHA)                             Default: 0.1    ! ALPHA = 0.1 !

      Multiplicative scaling factor for
      extrapolation of surface observations
      to upper layers (FEXTR2(NZ))        Default: NZ*0.0
      ! FEXTR2 = 0., 0., 0., 0., 0., 0., 0., 0. !
      (Used only if IEXTRP = 3 or -3)


   BARRIER INFORMATION

      Number of barriers to interpolation
      of the wind fields (NBAR)           Default: 0      ! NBAR =  0  !

      THE FOLLOWING 4 VARIABLES ARE INCLUDED
      ONLY IF NBAR > 0
      NOTE: NBAR values must be entered   No defaults
            for each variable             Units: km

         X coordinate of BEGINNING
         of each barrier (XBBAR(NBAR))    ! XBBAR = 0. !
         Y coordinate of BEGINNING
         of each barrier (YBBAR(NBAR))    ! YBBAR = 0. !

         X coordinate of ENDING
         of each barrier (XEBAR(NBAR))    ! XEBAR = 0. !
         Y coordinate of ENDING
         of each barrier (YEBAR(NBAR))    ! YEBAR = 0. !
```

```
DIAGNOSTIC MODULE DATA INPUT OPTIONS

   Surface temperature (IDIOPT1)         Default: 0      ! IDIOPT1 =  0  !
      0 = Compute internally from
          hourly surface observations
      1 = Read preprocessed values from
          a data file (DIAG.DAT)

      Surface met. station to use for
      the surface temperature (ISURFT)   No default     ! ISURFT =  3  !
      (Must be a value from 1 to NSSTA)
      (Used only if IDIOPT1 = 0)
      --------------------------

   Domain-averaged temperature lapse
   rate (IDIOPT2)                        Default: 0     ! IDIOPT2 =  0  !
      0 = Compute internally from
          twice-daily upper air observations
      1 = Read hourly preprocessed values
          from a data file (DIAG.DAT)

      Upper air station to use for
      the domain-scale lapse rate (IUPT) No default     ! IUPT   =  1  !
      (Must be a value from 1 to NUSTA)
      (Used only if IDIOPT2 = 0)
      --------------------------

      Depth through which the domain-scale
      lapse rate is computed (ZUPT)      Default: 200.  ! ZUPT = 200. !
      (Used only if IDIOPT2 = 0)         Units: meters
      --------------------------

   Domain-averaged wind components
   (IDIOPT3)                             Default: 0     ! IDIOPT3 =  0  !
      0 = Compute internally from
          twice-daily upper air observations
      1 = Read hourly preprocessed values
          a data file (DIAG.DAT)

      Upper air station to use for
      the domain-scale winds (IUPWND)    Default: -1    ! IUPWND = -1  !
      (Must be a value from -1 to NUSTA)
      (Used only if IDIOPT3 = 0)
      --------------------------

      Bottom and top of layer through
      which the domain-scale winds
      are computed
      (ZUPWND(1), ZUPWND(2))        Defaults: 1., 1000. ! ZUPWND= 1., 2000. !
      (Used only if IDIOPT3 = 0)    Units: meters
      --------------------------

   Observed surface wind components
   for wind field module (IDIOPT4)  Default: 0     ! IDIOPT4 =  0  !
      0 = Read WS, WD from a surface
          data file (SURF.DAT)
      1 = Read hourly preprocessed U, V from
          a data file (DIAG.DAT)

   Observed upper air wind components
   for wind field module (IDIOPT5)  Default: 0     ! IDIOPT5 =  0  !
      0 = Read WS, WD from an upper
          air data file (UP1.DAT, UP2.DAT, etc.)
      1 = Read hourly preprocessed U, V from
          a data file (DIAG.DAT)

   LAKE BREEZE INFORMATION

      Use Lake Breeze Module  (LLBREZE)
                                       Default: F      ! LLBREZE = F !

       Number of lake breeze regions (NBOX)            ! NBOX =  0  !

    X Grid line 1 defining the region of interest
                                                    ! XG1 = 0. !
    X Grid line 2 defining the region of interest
                                                    ! XG2 = 0. !
    Y Grid line 1 defining the region of interest
                                                    ! YG1 = 0. !
    Y Grid line 2 defining the region of interest
                                                    ! YG2 = 0. !

     X Point defining the coastline (Straight line)
               (XBCST)  (KM)   Default: none    ! XBCST = 0. !

     Y Point defining the coastline (Straight line)
               (YBCST)  (KM)   Default: none    ! YBCST = 0. !

     X Point defining the coastline (Straight line)
```

```
               (XECST)  (KM)   Default: none    ! XECST = 0. !

          Y Point defining the coastline (Straight line)
               (YECST)  (KM)   Default: none    ! YECST = 0. !



        Number of stations in the region     Default: none ! NLB = *1 !*
        (Surface stations + upper air stations)

        Station ID's  in the region   (METBXID(NLB))
        (Surface stations first, then upper air stations)
          ! METBXID = *0 !*

!END!


-------------------------------------------------------------------------------

INPUT GROUP: 6 -- Mixing Height, Temperature and Precipitation Parameters
--------------

    EMPIRICAL MIXING HEIGHT CONSTANTS

       Neutral, mechanical equation
       (CONSTB)                          Default: 1.41   ! CONSTB = 1.41 !
       Convective mixing ht. equation
       (CONSTE)                          Default: 0.15   ! CONSTE = 0.15 !
       Stable mixing ht. equation
       (CONSTN)                          Default: 2400.  ! CONSTN = 2400.!
       Overwater mixing ht. equation
       (CONSTW)                          Default: 0.16   ! CONSTW = 0.16 !
       Absolute value of Coriolis
       parameter (FCORIOL)               Default: 1.E-4  ! FCORIOL = 1.0E-04!
                                         Units: (1/s)

    SPATIAL AVERAGING OF MIXING HEIGHTS

       Conduct spatial averaging
       (IAVEZI)  (0=no, 1=yes)           Default: 1      ! IAVEZI =  1  !

       Max. search radius in averaging
       process (MNMDAV)                  Default: 1      ! MNMDAV =  3  !
                                         Units: Grid
                                                cells
       Half-angle of upwind looking cone
       for averaging (HAFANG)            Default: 30.    ! HAFANG = 30. !
                                         Units: deg.
       Layer of winds used in upwind
       averaging (ILEVZI)                Default: 1      ! ILEVZI =  1  !
       (must be between 1 and NZ)

    OTHER MIXING HEIGHT VARIABLES

       Minimum potential temperature lapse
       rate in the stable layer above the
       current convective mixing ht.     Default: 0.001  ! DPTMIN = 0.001 !
       (DPTMIN)                          Units: deg. K/m
       Depth of layer above current conv.
       mixing height through which lapse  Default: 200.   ! DZZI = 200. !
       rate is computed (DZZI)           Units: meters

       Minimum overland mixing height    Default:  50.   ! ZIMIN = 50. !
       (ZIMIN)                           Units: meters
       Maximum overland mixing height    Default: 3000.  ! ZIMAX = 3000. !
       (ZIMAX)                           Units: meters
       Minimum overwater mixing height   Default:   50.  ! ZIMINW = 50. !
       (ZIMINW) -- (Not used if observed  Units: meters
       overwater mixing hts. are used)
       Maximum overwater mixing height   Default: 3000.  ! ZIMAXW = 3000. !
       (ZIMAXW) -- (Not used if observed  Units: meters
       overwater mixing hts. are used)


    TEMPERATURE PARAMETERS

       Interpolation type
       (1 = 1/R ; 2 = 1/R**2)            Default:1         ! IRAD =  1  !

       Radius of influence for temperature
       interpolation (TRADKM)            Default: 500.     ! TRADKM = 500. !
                                         Units: km

       Maximum Number of stations to include
       in temperature interpolation (NUMTS)  Default: 5        ! NUMTS = 5  !

       Conduct spatial averaging of temp-
       eratures (IAVET)  (0=no, 1=yes)      Default: 1     ! IAVET =  1  !
       (will use mixing ht MNMDAV,HAFANG
```

```
        so make sure they are correct)

       Default temperature gradient        Default: -.0098 ! TGDEFB = -0.0098 !
       below the mixing height over
       water (K/m) (TGDEFB)

       Default temperature gradient        Default: -.0045 ! TGDEFA = -0.0045 !
       above the mixing height over
       water (K/m) (TGDEFA)

       Beginning (JWAT1) and ending (JWAT2)
       land use categories for temperature                   ! JWAT1 =  9999  !
       interpolation over water -- Make                      ! JWAT2 =  9999  !
       bigger than largest land use to disable

   PRECIP INTERPOLATION PARAMETERS

       Method of interpolation (NFLAGP)      Default = 2    ! NFLAGP =  3  !
        (1=1/R,2=1/R**2,3=EXP/R**2)
       Radius of Influence (km) (SIGMAP)     Default = 100.0  ! SIGMAP = 1. !
        (0.0 => use half dist. btwn
         nearest stns w & w/out
         precip when NFLAGP = 3)
       Minimum Precip. Rate Cutoff (mm/hr)   Default = 0.01  ! CUTP = 1. !
        (values < CUTP = 0.0 mm/hr)
!END!

-------------------------------------------------------------------------------

INPUT GROUP: 7 -- Surface meteorological station parameters
--------------

     SURFACE STATION VARIABLES
     (One record per station --  7  records in all)


             1     2
         Name   ID            X coord.   Y coord.   Time   Anem.
                                (km)       (km)      zone   Ht.(m)
       ----------------------------------------------------------
! SS1  ='AES'   10964       524.070     5976.880    8    10  !
! SS2  ='UNI'       2       512.196     5971.667    8    10  !
! SS3  ='PLZ'       3       517.000     5973.975    8    10  !
! SS4  ='PGP'       4       520.750     5974.650    8    10  !
! SS5  ='NRD'       5       520.750     5979.750    8    10  !
! SS6  ='GLN'       6       514.714     5982.830    8    10  !
! SS7  ='GLD'       7       515.600     5969.400    8    10  !
-------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Five digit integer for station ID

!END!


-------------------------------------------------------------------------------

INPUT GROUP: 8 -- Upper air meteorological station parameters
--------------

     UPPER AIR STATION VARIABLES
     (One record per station --  1  records in all)

             1     2
         Name    ID      X coord.   Y coord.  Time zone
                           (km)       (km)
        -----------------------------------------------
! US1  ='Up1'       1    513.142   5972.190    8  !
-------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Five digit integer for station ID

!END!


-------------------------------------------------------------------------------

INPUT GROUP: 9 -- Precipitation station parameters
--------------

     PRECIPITATION STATION VARIABLES
```

```
     (One record per station --  0  records in all)
     (NOT INCLUDED IF NPSTA = 0)

            1          2
         Name   Station    X coord.  Y coord.
                  Code       (km)      (km)
         ------------------------------------


-------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Six digit station code composed of state
        code (first 2 digits) and station ID (last
        4 digits)

!END!
```

C.9. CALPUFF Initialization File

```
CALPUFF RUN USING CALMET FIELDS DERIVED FROM RAMS SIMULATED
SURFACE AND UPPER AIR STATIONS.
JANUARY 28 - FEBRUARY 1

---------------- Run title (3 lines) ------------------------------------------

                    CALPUFF MODEL CONTROL FILE
                    --------------------------

-------------------------------------------------------------------------------

INPUT GROUP: 0 -- Input and Output File Names

--------------
Default Name  Type          File Name
------------  ----          ---------
CALMET.DAT    input    ! METDAT =C:\CALFINAL\CMETOUT\JAN\JAN\JAN.DAT   !
    or
ISCMET.DAT    input    * ISCDAT =             *
    or
PLMMET.DAT    input    * PLMDAT =             *
    or
PROFILE.DAT   input    * PRFDAT =             *
SURFACE.DAT   input    * SFCDAT =             *
RESTARTB.DAT  input    * RSTARTB=             *
--------------------------------------------------------------------------------
CALPUFF.LST   output   ! PUFLST =C:\CALFINAL\PUFFOUT\JAN\JANPN.LST  !
CONC.DAT      output   ! CONDAT =C:\CALFINAL\PUFFOUT\JAN\JANPN.CON     !
DFLX.DAT      output   * DFDAT  =             *
WFLX.DAT      output   * WFDAT  =             *

VISB.DAT      output   * VISDAT =             *
RESTARTE.DAT  output   * RSTARTE=             *
--------------------------------------------------------------------------------
Emission Files
--------------
PTEMARB.DAT   input    * PTDAT  =             *
VOLEMARB.DAT  input    * VOLDAT =             *
BAEMARB.DAT   input    * ARDAT  =             *
LNEMARB.DAT   input    * LNDAT  =             *
--------------------------------------------------------------------------------
Other Files
-----------
OZONE.DAT     input    * OZDAT  =             *
VD.DAT        input    * VDDAT  =             *
CHEM.DAT      input    * CHEMDAT=             *
HILL.DAT      input    * HILDAT=             *
HILLRCT.DAT   input    * RCTDAT=             *
COASTLN.DAT   input    * CSTDAT=             *
FLUXBDY.DAT   input    * BDYDAT=             *
BCON.DAT      input    * BCNDAT=             *
DEBUG.DAT     output   * DEBUG =             *
MASSFLX.DAT   output   * FLXDAT=             *
MASSBAL.DAT   output   * BALDAT=             *
FOG.DAT       output   * FOGDAT=             *
--------------------------------------------------------------------------------
All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
         T = lower case      ! LCFILES = F !
         F = UPPER CASE
NOTE: (1) file/path names can be up to 70 characters in length


Provision for multiple input files
----------------------------------

     Number of CALMET.DAT files for run (NMETDAT)
                                     Default: 1       ! NMETDAT =   1   !

     Number of PTEMARB.DAT files for run (NPTDAT)
                                     Default: 0       ! NPTDAT =  0  !

     Number of BAEMARB.DAT files for run (NARDAT)
                                     Default: 0       ! NARDAT =  0  !

     Number of VOLEMARB.DAT files for run (NVOLDAT)
                                     Default: 0       ! NVOLDAT =  0  !

!END!

-------------
Subgroup (0a)
-------------

  The following CALMET.DAT filenames are processed in sequence if NMETDAT>1

Default Name  Type          File Name
```

```
------------  ----          ---------
 none         input    * METDAT=     *   *END*


-------------------------------------------------------------------------------

INPUT GROUP: 1 -- General run control parameters
--------------

    Option to run all periods found
    in the met. file     (METRUN)   Default: 0       ! METRUN =   1  !

         METRUN = 0 - Run period explicitly defined below
         METRUN = 1 - Run all periods in met. file

     Starting date:   Year (IBYR) -- No default       ! IBYR =  1999  !
     (used only if   Month (IBMO) -- No default       ! IBMO =  0  !
      METRUN = 0)      Day (IBDY) -- No default       ! IBDY =  0  !
                      Hour (IBHR) -- No default       ! IBHR =  0  !

     Length of run (hours) (IRLG) -- No default       ! IRLG =  0  !

     Number of chemical species (NSPEC)
                                  Default: 5       ! NSPEC =  1   !

     Number of chemical species
     to be emitted  (NSE)         Default: 3       ! NSE =  1   !

     Flag to stop run after
     SETUP phase (ITEST)          Default: 2       ! ITEST =  2   !
     (Used to allow checking
     of the model inputs, files, etc.)
           ITEST = 1 - STOPS program after SETUP phase
           ITEST = 2 - Continues with execution of program
                       after SETUP

     Restart Configuration:

        Control flag (MRESTART)      Default: 0       ! MRESTART =  0   !

           0 = Do not read or write a restart file
           1 = Read a restart file at the beginning of
               the run
           2 = Write a restart file during run
           3 = Read a restart file at beginning of run
               and write a restart file during run

        Number of periods in Restart
        output cycle (NRESPD)        Default: 0       ! NRESPD =  0   !

           0 = File written only at last period
          >0 = File updated every NRESPD periods

     Meteorological Data Format (METFM)
                                  Default: 1       ! METFM =  1   !

           METFM = 1 - CALMET binary file (CALMET.MET)
           METFM = 2 - ISC ASCII file (ISCMET.MET)
           METFM = 3 - AUSPLUME ASCII file (PLMMET.MET)
           METFM = 4 - CTDM plus tower file (PROFILE.DAT) and
                       surface parameters file (SURFACE.DAT)

     PG sigma-y is adjusted by the factor (AVET/PGTIME)**0.2
     Averaging Time (minutes) (AVET)
                                  Default: 60.0    ! AVET = 60. !
     PG Averaging Time (minutes) (PGTIME)
                                  Default: 60.0    ! PGTIME = 60. !


!END!


-------------------------------------------------------------------------------

INPUT GROUP: 2 -- Technical options
--------------


     Vertical distribution used in the
     near field (MGAUSS)                Default: 1     ! MGAUSS =  1   !
        0 = uniform
        1 = Gaussian

     Terrain adjustment method
     (MCTADJ)                           Default: 3     ! MCTADJ =  1   !
        0 = no adjustment
        1 = ISC-type of terrain adjustment
        2 = simple, CALPUFF-type of terrain
            adjustment
```

```
   3 = partial plume path adjustment

Subgrid-scale complex terrain
flag (MCTSG)                         Default: 0     ! MCTSG =  0   !
   0 = not modeled
   1 = modeled

Near-field puffs modeled as
elongated 0 (MSLUG)                  Default: 0     ! MSLUG =  0   !
   0 = no
   1 = yes (slug model used)

Transitional plume rise modeled ?
(MTRANS)                             Default: 1     ! MTRANS =  1   !
   0 = no  (i.e., final rise only)
   1 = yes (i.e., transitional rise computed)

Stack tip downwash? (MTIP)           Default: 1     ! MTIP =  1  !
   0 = no  (i.e., no stack tip downwash)
   1 = yes (i.e., use stack tip downwash)

Vertical wind shear modeled above
stack top? (MSHEAR)                  Default: 0     ! MSHEAR =  1  !
   0 = no  (i.e., vertical wind shear not modeled)
   1 = yes (i.e., vertical wind shear modeled)

Puff splitting allowed? (MSPLIT)     Default: 0     ! MSPLIT =  0  !
   0 = no (i.e., puffs not split)
   1 = yes (i.e., puffs are split)

Chemical mechanism flag (MCHEM)      Default: 1     ! MCHEM =  0   !
   0 = chemical transformation not
       modeled
   1 = transformation rates computed
       internally (MESOPUFF II scheme)
   2 = user-specified transformation
       rates used
   3 = transformation rates computed
       internally (RIVAD/ARM3 scheme)
   4 = secondary organic aerosol formation
       computed (MESOPUFF II scheme for OH)

Wet removal modeled ? (MWET)         Default: 1     ! MWET =  0   !
   0 = no
   1 = yes

Dry deposition modeled ? (MDRY)      Default: 1     ! MDRY =  0   !
   0 = no
   1 = yes
   (dry deposition method specified
    for each species in Input Group 3)

Method used to compute dispersion
coefficients (MDISP)                 Default: 3     ! MDISP =  3   !

   1 = dispersion coefficients computed from measured values
       of turbulence, sigma v, sigma w
   2 = dispersion coefficients from internally calculated
       sigma v, sigma w using micrometeorological variables
       (u*, w*, L, etc.)
   3 = PG dispersion coefficients for RURAL areas (computed using
       the ISCST multi-segment approximation) and MP coefficients in
       urban areas
   4 = same as 3 except PG coefficients computed using
       the MESOPUFF II eqns.
   5 = CTDM sigmas used for stable and neutral conditions.
       For unstable conditions, sigmas are computed as in
       MDISP = 3, described above.  MDISP = 5 assumes that
       measured values are read

Sigma-v/sigma-theta, sigma-w measurements used? (MTURBVW)
(Used only if MDISP = 1 or 5)        Default: 3     ! MTURBVW =  3  !
   1 = use sigma-v or sigma-theta measurements
       from PROFILE.DAT to compute sigma-y
       (valid for METFM = 1, 2, 3, 4)
   2 = use sigma-w measurements
       from PROFILE.DAT to compute sigma-z
       (valid for METFM = 1, 2, 3, 4)
   3 = use both sigma-(v/theta) and sigma-w
       from PROFILE.DAT to compute sigma-y and sigma-z
       (valid for METFM = 1, 2, 3, 4)
   4 = use sigma-theta measurements
       from PLMMET.DAT to compute sigma-y
       (valid only if METFM = 3)

Back-up method used to compute dispersion
when measured turbulence data are
missing (MDISP2)                     Default: 3     ! MDISP2 =  3  !
(used only if MDISP = 1 or 5)
```

```
   2 = dispersion coefficients from internally calculated
       sigma v, sigma w using micrometeorological variables
       (u*, w*, L, etc.)
   3 = PG dispersion coefficients for RURAL areas (computed using
       the ISCST multi-segment approximation) and MP coefficients in
       urban areas
   4 = same as 3 except PG coefficients computed using
       the MESOPUFF II eqns.

PG sigma-y,z adj. for roughness?      Default: 0     ! MROUGH =  0  !
(MROUGH)
   0 = no
   1 = yes

Partial plume penetration of          Default: 1     ! MPARTL =  0  !
elevated inversion?
(MPARTL)
   0 = no
   1 = yes

Strength of temperature inversion     Default: 0     ! MTINV =  0  !
provided in PROFILE.DAT extended records?
(MTINV)
   0 = no (computed from measured/default gradients)
   1 = yes

PDF used for dispersion under convective conditions?
                                      Default: 0     ! MPDF =  0  !
(MPDF)
   0 = no
   1 = yes

Sub-Grid TIBL module used for shore line?
                                      Default: 0     ! MSGTIBL = 0  !
(MSGTIBL)
   0 = no
   1 = yes

Boundary conditions (concentration) modeled?
                                      Default: 0     ! MBCON = 0  !
(MBCON)
   0 = no
   1 = yes


Analyses of fogging and icing impacts due to emissions from
arrays of mechanically-forced cooling towers can be performed
using CALPUFF in conjunction with a cooling tower emissions
processor (CTEMISS) and its associated postprocessors.  Hourly
emissions of water vapor and temperature from each cooling tower
cell are computed for the current cell configuration and ambient
conditions by CTEMISS. CALPUFF models the dispersion of these
emissions and provides cloud information in a specialized format
for further analysis. Output to FOG.DAT is provided in either
'plume mode' or 'receptor mode' format.

Configure for FOG Model output?
                                      Default: 0     ! MFOG =  0  !
(MFOG)
   0 = no
   1 = yes  - report results in PLUME Mode format
   2 = yes  - report results in RECEPTOR Mode format


Test options specified to see if
they conform to regulatory
values? (MREG)                        Default: 1     ! MREG =  0   !

   0 = NO checks are made
   1 = Technical options must conform to USEPA values
                  METFM    1
                  AVET     60. (min)
                  MGAUSS   1
                  MCTADJ   3
                  MTRANS   1
                  MTIP     1
                  MCHEM    1 (if modeling SOx, NOx)
                  MWET     1
                  MDRY     1
                  MDISP    3
                  MROUGH   0
                  MPARTL   1
                  SYTDEP   550. (m)
                  MHFTSZ   0

!END!
```

```
-------------------------------------------------------------------------------

INPUT GROUP: 3a, 3b -- Species list
-------------------

------------
Subgroup (3a)
------------

  The following species are modeled:

! CSPEC =          SO2 !         !END!

                                                       Dry                 OUTPUT GROUP
    SPECIES          MODELED          EMITTED       DEPOSITED                NUMBER
     NAME         (0=NO, 1=YES)    (0=NO, 1=YES)    (0=NO,                 (0=NONE,
   (Limit: 12                                        1=COMPUTED-GAS         1=1st CGRUP,
    Characters                                       2=COMPUTED-PARTICLE   2=2nd CGRUP,
    in length)                                       3=USER-SPECIFIED)     3= etc.)

!          SO2  =         1,               1,           0,                 0   !

!END!

-------------
Subgroup (3b)
-------------
  The following names are used for Species-Groups in which results
  for certain species are combined (added) prior to output.  The
  CGRUP name will be used as the species name in output files.
  Use this feature to model specific particle-size distributions
  by treating each size-range as a separate species.
  Order must be consistent with 3(a) above.



-------------------------------------------------------------------------------


INPUT GROUP: 4 -- Grid control parameters
--------------


METEOROLOGICAL grid:

            No. X grid cells (NX)      No default     ! NX =  49   !
            No. Y grid cells (NY)      No default     ! NY =  49   !
         No. vertical layers (NZ)      No default     ! NZ =  8   !

           Grid spacing (DGRIDKM)      No default     ! DGRIDKM = 0.5 !
                                       Units: km

                Cell face heights
                    (ZFACE(nz+1))      No defaults
                                       Units: m
   ! ZFACE = 0., 20., 50., 100., 250., 500., 1000., 1500., 3500. !

            Reference Coordinates
           of SOUTHWEST corner of
                 grid cell(1, 1):

            X coordinate (XORIGKM)     No default     ! XORIGKM = 505. !
            Y coordinate (YORIGKM)     No default     ! YORIGKM = 5966. !
                                      Units: km

                 UTM zone (IUTMZN)     No default     ! IUTMZN =  10   !

   Reference coordinates of CENTER
        of the domain (used in the
    calculation of solar elevation
                           angles)

            Latitude  (deg.) (XLAT)    No default     ! XLAT  = 53.957  !
           Longitude (deg.) (XLONG)    No default     ! XLONG = 122.73  !
             Time zone        (XTZ)    No default     ! XTZ   = 8.0  !
       (PST=8, MST=7, CST=6, EST=5)


Computational grid:

     The computational grid is identical to or a subset of the MET. grid.
     The lower left (LL) corner of the computational grid is at grid point
     (IBCOMP, JBCOMP) of the MET. grid.  The upper right (UR) corner of the
     computational grid is at grid point (IECOMP, JECOMP) of the MET. grid.
     The grid spacing of the computational grid is the same as the MET. grid.

        X index of LL corner (IBCOMP)      No default     ! IBCOMP =  1   !
                  (1 <= IBCOMP <= NX)
```

```
        Y index of LL corner (JBCOMP)      No default     ! JBCOMP =  1   !
                  (1 <= JBCOMP <= NY)


        X index of UR corner (IECOMP)      No default     ! IECOMP =  49   !
                  (1 <= IECOMP <= NX)

        Y index of UR corner (JECOMP)      No default     ! JECOMP =  49   !
                  (1 <= JECOMP <= NY)



SAMPLING GRID (GRIDDED RECEPTORS):

     The lower left (LL) corner of the sampling grid is at grid point
     (IBSAMP, JBSAMP) of the MET. grid.  The upper right (UR) corner of the
     sampling grid is at grid point (IESAMP, JESAMP) of the MET. grid.
     The sampling grid must be identical to or a subset of the computational
     grid.  It may be a nested grid inside the computational grid.
     The grid spacing of the sampling grid is DGRIDKM/MESHDN.

        Logical flag indicating if gridded
        receptors are used (LSAMP)         Default: T     ! LSAMP = F !
        (T=yes, F=no)

        X index of LL corner (IBSAMP)      No default     ! IBSAMP =  1   !
         (IBCOMP <= IBSAMP <= IECOMP)

        Y index of LL corner (JBSAMP)      No default     ! JBSAMP =  1   !
         (JBCOMP <= JBSAMP <= JECOMP)


        X index of UR corner (IESAMP)      No default     ! IESAMP =  49   !
         (IBCOMP <= IESAMP <= IECOMP)

        Y index of UR corner (JESAMP)      No default     ! JESAMP =  49   !
         (JBCOMP <= JESAMP <= JECOMP)


       Nesting factor of the sampling
        grid (MESHDN)                      Default: 1     ! MESHDN =  1  !
        (MESHDN is an integer >= 1)

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 5 -- Output Options
--------------
                                             *                          *
     FILE                       DEFAULT VALUE             VALUE THIS RUN
     ----                       -------------             --------------

   Concentrations (ICON)              1                   !  ICON =  1   !
   Dry Fluxes (IDRY)                  1                   !  IDRY =  0   !
   Wet Fluxes (IWET)                  1                   !  IWET =  0   !
   Relative Humidity (IVIS)           1                   !  IVIS =  0   !
    (relative humidity file is
     required for visibility
     analysis)
   Use data compression option in output file?
   (LCOMPRS)                           Default: T         ! LCOMPRS = F !

   *
    0 = Do not create file, 1 = create file


    DIAGNOSTIC MASS FLUX OUTPUT OPTIONS:

       Mass flux across specified boundaries
       for selected species reported hourly?
       (IMFLX)                         Default: 0         ! IMFLX =  0  !
         0 = no
         1 = yes (FLUXBDY.DAT and MASSFLX.DAT filenames
                  are specified in Input Group 0)

       Mass balance for each species
       reported hourly?
       (IMBAL)                         Default: 0         ! IMBAL =  0  !
         0 = no
         1 = yes (MASSBAL.DAT filename is
              specified in Input Group 0)


    LINE PRINTER OUTPUT OPTIONS:
```

```
       Print concentrations (ICPRT)    Default: 0         ! ICPRT =  1   !
       Print dry fluxes (IDPRT)        Default: 0         ! IDPRT =  0   !
       Print wet fluxes (IWPRT)        Default: 0         ! IWPRT =  0   !
       (0 = Do not print, 1 = Print)

       Concentration print interval
       (ICFRQ) in hours                Default: 1         ! ICFRQ =  1   !
       Dry flux print interval
       (IDFRQ) in hours                Default: 1         ! IDFRQ =  1   !
       Wet flux print interval
       (IWFRQ) in hours                Default: 1         ! IWFRQ =  1   !

       Units for Line Printer Output
       (IPRTU)                         Default: 1         ! IPRTU =  3   !
                       for            for
                  Concentration    Deposition
           1 =       g/m**3         g/m**2/s
           2 =      mg/m**3        mg/m**2/s
           3 =      ug/m**3        ug/m**2/s
           4 =      ng/m**3        ng/m**2/s
           5 =     Odour Units

       Messages tracking progress of run
       written to the screen ?
       (IMESG)                         Default: 2         ! IMESG =  2   !
         0 = no
         1 = yes (advection step, puff ID)
         2 = yes (YYYYJJJHH, # old puffs, # emitted puffs)


     SPECIES (or GROUP for combined species) LIST FOR OUTPUT OPTIONS

                 ---- CONCENTRATIONS ----   ------ DRY FLUXES ------   ------ WET FLUXES ------   -- MASS FLUX --
   SPECIES
   /GROUP        PRINTED?  SAVED ON DISK?   PRINTED?  SAVED ON DISK?   PRINTED?  SAVED ON DISK?   SAVED ON DISK?
   -------       ------------------------   ------------------------   ------------------------   ---------------
!         SO2 =     1,           1,            0,           0,            0,           0,            0   !

     OPTIONS FOR PRINTING "DEBUG" QUANTITIES (much output)

       Logical for debug output
       (LDEBUG)                                 Default: F     ! LDEBUG = F !

       First puff to track
       (IPFDEB)                                 Default: 1     ! IPFDEB =  1  !

       Number of puffs to track
       (NPFDEB)                                 Default: 1     ! NPFDEB =  1  !

       Met. period to start output
       (NN1)                                    Default: 1     ! NN1 =  1   !

       Met. period to end output
       (NN2)                                    Default: 10    ! NN2 =  108  !

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 6a, 6b, & 6c -- Subgrid scale complex terrain inputs
-------------------------

---------------
Subgroup (6a)
---------------
       Number of terrain features (NHILL)       Default: 0     ! NHILL =  0   !

       Number of special complex terrain
       receptors  (NCTREC)                      Default: 0     ! NCTREC =  0   !

       Terrain and CTSG Receptor data for
       CTSG hills input in CTDM format ?
       (MHILL)                                  No Default     ! MHILL =  2   !
       1 = Hill and Receptor data created
           by CTDM processors & read from
           HILL.DAT and HILLRCT.DAT files
       2 = Hill data created by OPTHILL &
           input below in Subgroup (6b);
           Receptor data in Subgroup (6c)

       Factor to convert horizontal dimensions  Default: 1.0   ! XHILL2M = 1. !
       to meters (MHILL=1)

       Factor to convert vertical dimensions    Default: 1.0   ! ZHILL2M = 1. !
       to meters (MHILL=1)

       X-origin of CTDM system relative to      No Default     ! XCTDMKM = 0.0E00 !
```

```
       CALPUFF coordinate system, in Kilometers (MHILL=1)

       Y-origin of CTDM system relative to      No Default     ! YCTDMKM = 0.0E00 !
       CALPUFF coordinate system, in Kilometers (MHILL=1)

! END !

---------------
Subgroup (6b)
---------------

                      1 **
     HILL information


HILL           XC        YC       THETAH  ZGRID  RELIEF    EXPO 1    EXPO 2   SCALE 1    SCALE 2    AMAX1     AMAX2
 NO.          (km)      (km)      (deg.)   (m)     (m)      (m)       (m)       (m)        (m)       (m)       (m)
----          ----      ----      ------  -----  ------    ------    ------   -------    -------    -----     -----

---------------
Subgroup (6c)
---------------

    COMPLEX TERRAIN RECEPTOR INFORMATION

                      XRCT         YRCT        ZRCT          XHH
                      (km)         (km)         (m)
                     ------        -----      ------         ----


-------------------
1
     Description of Complex Terrain Variables:
          XC, YC  = Coordinates of center of hill
          THETAH  = Orientation of major axis of hill (clockwise from
                    North)
          ZGRID   = Height of the  0  of the grid above mean sea
                    level
          RELIEF  = Height of the crest of the hill above the grid elevation
          EXPO 1  = Hill-shape exponent for the major axis
          EXPO 2  = Hill-shape exponent for the major axis
          SCALE 1 = Horizontal length scale along the major axis
          SCALE 2 = Horizontal length scale along the minor axis
          AMAX    = Maximum allowed axis length for the major axis
          BMAX    = Maximum allowed axis length for the major axis

          XRCT, YRCT = Coordinates of the complex terrain receptors
          ZRCT    = Height of the ground (MSL) at the complex terrain
                    Receptor
          XHH     = Hill number associated with each complex terrain receptor
                     (NOTE: MUST BE ENTERED AS A REAL NUMBER)

   **
     NOTE: DATA for each hill and CTSG receptor are treated as a separate
           input subgroup and therefore must end with an input group terminator.

-------------------------------------------------------------------------------


INPUT GROUP: 7 -- Chemical parameters for dry deposition of gases
--------------

      SPECIES     DIFFUSIVITY      ALPHA STAR      REACTIVITY    MESOPHYLL RESISTANCE     HENRY'S LAW COEFFICIENT
       NAME        (cm**2/s)                                            (s/cm)                 (dimensionless)
      -------     -----------      ----------      ----------    --------------------     -----------------------


!END!


-------------------------------------------------------------------------------


INPUT GROUP: 8 -- Size parameters for dry deposition of particles
--------------

     For SINGLE SPECIES, the mean and standard deviation are used to
     compute a deposition velocity for NINT (see group 9) size-ranges,
     and these are then averaged to obtain a mean deposition velocity.

     For GROUPED SPECIES, the size distribution should be explicitly
     specified (by the 'species' in the group), and the standard deviation
     for each should be entered as 0.  The model will then use the
     deposition velocity for the stated mean diameter.

      SPECIES      GEOMETRIC MASS MEAN        GEOMETRIC STANDARD
       NAME             DIAMETER                   DEVIATION
                        (microns)                  (microns)
      -------      -------------------        ------------------
```

```
!END!


-------------------------------------------------------------------------------


INPUT GROUP: 9 -- Miscellaneous dry deposition parameters
--------------

     Reference cuticle resistance (s/cm)
     (RCUTR)                          Default: 30    !  RCUTR = 30.0 !
     Reference ground resistance  (s/cm)
     (RGR)                            Default: 10    !    RGR = 10.0 !
     Reference pollutant reactivity
     (REACTR)                         Default: 8     ! REACTR = 8.0 !

     Number of particle-size intervals used to
     evaluate effective particle deposition velocity
     (NINT)                           Default: 9     !   NINT =  9  !

     Vegetation state in unirrigated areas
     (IVEG)                           Default: 1     !   IVEG =  1   !
        IVEG=1 for active and unstressed vegetation
        IVEG=2 for active and stressed vegetation
        IVEG=3 for inactive vegetation

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 10 -- Wet Deposition Parameters
---------------


                      Scavenging Coefficient -- Units: (sec)**(-1)

       Pollutant      Liquid Precip.       Frozen Precip.
       ---------      --------------       -------------

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 11 -- Chemistry Parameters
---------------

     Ozone data input option (MOZ)     Default: 1            ! MOZ =  1   !
     (Used only if MCHEM = 1, 3, or 4)
        0 = use a constant background ozone value
        1 = read hourly ozone concentrations from
            the OZONE.DAT data file

     Background ozone concentration
     (BCKO3) in ppb                   Default: 80.          ! BCKO3 = 80.0 !
     (Used only if MCHEM = 1, 3, or 4 and
      MOZ = 0 or (MOZ = 1 and all hourly
      O3 data missing)

     Background ammonia concentration
     (BCKNH3) in ppb                  Default: 10.          ! BCKNH3 = 10.0 !

     Nighttime SO2 loss rate (RNITE1)
     in percent/hour                  Default: 0.2          ! RNITE1 = .2 !

     Nighttime NOx loss rate (RNITE2)
     in percent/hour                  Default: 2.0          ! RNITE2 = 2.0 !

     Nighttime HNO3 formation rate (RNITE3)
     in percent/hour                  Default: 2.0          ! RNITE3 = 2.0 !

 --- Data for SECONDARY ORGANIC AEROSOL (SOA) Option
     (used only if MCHEM = 4)

     The SOA module uses monthly values of:
          Fine particulate concentration in ug/m^3 (BCKPMF)
          Organic fraction of fine particulate     (OFRAC)
          VOC / NOX ratio (after reaction)         (VCNX)
     to characterize the air mass when computing
     the formation of SOA from VOC emissions.
     Typical values for several distinct air mass types are:

        Month    1    2    3    4    5    6    7    8    9   10   11   12
                Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec
```

```
     Clean Continental
        BCKPMF   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
        OFRAC  .15  .15  .20  .20  .20  .20  .20  .20  .20  .20  .20  .15
        VCNX    50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.

     Clean Marine (surface)
        BCKPMF  .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
        OFRAC  .25  .25  .30  .30  .30  .30  .30  .30  .30  .30  .30  .25
        VCNX    50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.

     Urban - low biogenic (controls present)
        BCKPMF  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.
        OFRAC  .20  .20  .25  .25  .25  .25  .25  .25  .20  .20  .20  .20
        VCNX     4.   4.   4.   4.   4.   4.   4.   4.   4.   4.   4.   4.

     Urban - high biogenic (controls present)
        BCKPMF  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.
        OFRAC  .25  .25  .30  .30  .30  .55  .55  .55  .35  .35  .35  .25
        VCNX    15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.

     Regional Plume
        BCKPMF  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
        OFRAC  .20  .20  .25  .35  .25  .40  .40  .40  .30  .30  .30  .20
        VCNX    15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.

     Urban - no controls present
        BCKPMF 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
        OFRAC  .30  .30  .35  .35  .35  .55  .55  .55  .35  .35  .35  .30
        VCNX     2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.

     Default: Clean Continental
     !  BCKPMF = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !
     !  OFRAC  = 0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15 !
     !  VCNX   = 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00 !


!END!


-------------------------------------------------------------------------------


INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters
---------------

     Horizontal size of puff (m) beyond which
     time-dependent dispersion equations (Heffter)
     are used to determine sigma-y and
     sigma-z (SYTDEP)                           Default: 550.   ! SYTDEP = 5.5E02 !

     Switch for using Heffter equation for sigma z
     as above (0 = Not use Heffter; 1 = use Heffter
     (MHFTSZ)                                   Default: 0      ! MHFTSZ =  0   !

     Stability class used to determine plume
     growth rates for puffs above the boundary
     layer (JSUP)                               Default: 5      ! JSUP =  5   !

     Vertical dispersion constant for stable
     conditions (k1 in Eqn. 2.7-3)  (CONK1)     Default: 0.01   ! CONK1 = .01 !

     Vertical dispersion constant for neutral/
     unstable conditions (k2 in Eqn. 2.7-4)
     (CONK2)                                    Default: 0.1    ! CONK2 = .1 !

     Factor for determining Transition-point from
     Schulman-Scire to Huber-Snyder Building Downwash
     scheme (SS used for Hs < Hb + TBD * HL)
     (TBD)                                      Default: 0.5    ! TBD = .5 !
        TBD < 0   ==> always use Huber-Snyder
        TBD = 1.5 ==> always use Schulman-Scire
        TBD = 0.5 ==> ISC Transition-point

     Range of land use categories for which
     urban dispersion is assumed
     (IURB1, IURB2)                             Default: 10     ! IURB1 =  10  !
                                                         19     ! IURB2 =  19  !

     Site characterization parameters for single-point Met data files ---------
     (needed for METFM = 2,3,4)

        Land use category for modeling domain
        (ILANDUIN)                              Default: 20     ! ILANDUIN =  20  !

        Roughness length (m) for modeling domain
        (Z0IN)                                  Default: 0.25   ! Z0IN = .25 !

        Leaf area index for modeling domain
        (XLAIIN)                                Default: 3.0    ! XLAIIN = 3.0 !
```

```
   Elevation above sea level (m)
   (ELEVIN)                            Default: 0.0    ! ELEVIN = .0 !

   Latitude (degrees) for met location
   (XLATIN)                            Default: -999.  ! XLATIN = -999.0 !

   Longitude (degrees) for met location
   (XLONIN)                            Default: -999.  ! XLONIN = -999.0 !

Specialized information for interpreting single-point Met data files -----

   Anemometer height (m) (Used only if METFM = 2,3)
   (ANEMHT)                            Default: 10.    ! ANEMHT = 10.0 !

   Form of lateral turbulance data in PROFILE.DAT file
   (Used only if METFM = 4 or MTURBVW = 1 or 3)
   (ISIGMAV)                           Default: 1      ! ISIGMAV =  1  !
       0 = read sigma-theta
       1 = read sigma-v

   Choice of mixing heights (Used only if METFM = 4)
   (IMIXCTDM)                          Default: 0      ! IMIXCTDM =  0  !
       0 = read PREDICTED mixing heights
       1 = read OBSERVED mixing heights

Maximum length of a slug (met. grid units)
(XMXLEN)                               Default: 1.0    ! XMXLEN = 1.0 !

Maximum travel distance of a puff/slug (in
grid units) during one sampling step
(XSAMLEN)                              Default: 1.0    ! XSAMLEN = 1.0 !

Maximum Number of slugs/puffs release from
one source during one time step
(MXNEW)                                Default: 99     ! MXNEW =  99   !

Maximum Number of sampling steps for
one puff/slug during one time step
(MXSAM)                                Default: 99     ! MXSAM =  99   !

Number of iterations used when computing
the transport wind for a sampling step
that includes gradual rise (for CALMET
and PROFILE winds)
(NCOUNT)                               Default: 2      ! NCOUNT =  2   !

Minimum sigma y for a new puff/slug (m)
(SYMIN)                                Default: 1.0    ! SYMIN = 1.0  !

Minimum sigma z for a new puff/slug (m)
(SZMIN)                                Default: 1.0    ! SZMIN = 1.0  !

Default minimum turbulence velocities
sigma-v and sigma-w for each
stability class (m/s)
(SVMIN(6) and SWMIN(6))     Default SVMIN : .50,  .50,  .50,  .50,  .50,  .50
                            Default SWMIN : .20,  .12,  .08,  .06,  .03,  .016

                          Stability Class :  A     B     C     D     E     F
                                            ---   ---   ---   ---   ---   ---
                                 ! SVMIN = 0.500, 0.500, 0.500, 0.500, 0.500, 0.500!
                                 ! SWMIN = 0.200, 0.120, 0.080, 0.060, 0.030, 0.016!

Divergence criterion for dw/dz across puff
used to initiate adjustment for horizontal
convergence (1/s)
Partial adjustment starts at CDIV(1), and
full adjustment is reached at CDIV(2)
(CDIV(2))                              Default: 0.0,0.0  ! CDIV = .0, .0 !

Minimum wind speed (m/s) allowed for
non-calm conditions. Also used as minimum
speed returned when using power-law
extrapolation toward surface
(WSCALM)                               Default: 0.5    ! WSCALM = .5 !

Maximum mixing height (m)
(XMAXZI)                               Default: 3000.  ! XMAXZI = 3000.0 !

Minimum mixing height (m)
(XMINZI)                               Default: 50.    ! XMINZI = 50.0 !

Default wind speed classes --
5 upper bounds (m/s) are entered;
the 6th class has no upper limit
(WSCAT(5))                      Default   :
                                ISC RURAL : 1.54, 3.09, 5.14, 8.23, 10,8 (10.8+)
```

```
                          Wind Speed Class :  1     2     3     4     5     6
                                             ---   ---   ---   ---   ---   ---
                                  ! WSCAT = 1.54, 3.09, 5.14, 8.23, 10.80 !

Default wind speed profile power-law
exponents for stabilities 1-6
(PLX0(6))                       Default   : ISC RURAL values
                                ISC RURAL : .07, .07, .10, .15, .35, .55
                                ISC URBAN : .15, .15, .20, .25, .30, .30

                          Stability Class :  A     B     C     D     E     F
                                             ---   ---   ---   ---   ---   ---
                                   ! PLX0 = 0.07, 0.07, 0.10, 0.15, 0.35, 0.55 !

Default potential temperature gradient
for stable classes E, F (degK/m)
(PTG0(2))                       Default: 0.020, 0.035
                                   ! PTG0 = 0.020,   0.035 !

Default plume path coefficients for
each stability class (used when option
for partial plume height terrain adjustment
is selected -- MCTADJ=3)
(PPC(6))                  Stability Class :  A     B     C     D     E     F
                             Default  PPC : .50,  .50,  .50,  .50,  .35,  .35
                                             ---   ---   ---   ---   ---   ---
                                   !  PPC = 0.50, 0.50, 0.50, 0.50, 0.35, 0.35 !

Slug-to-puff transition criterion factor
equal to sigma-y/length of slug
(SL2PF)                               Default: 10.       ! SL2PF = 10.0 !

Puff-splitting control variables ------------------------

  VERTICAL SPLIT
  --------------

  Number of puffs that result every time a puff
  is split - nsplit=2 means that 1 puff splits
  into 2
  (NSPLIT)                            Default:   3       ! NSPLIT =  3  !

  Time(s) of a day when split puffs are eligible to
  be split once again; this is typically set once
  per day, around sunset before nocturnal shear develops.
  24 values: 0 is midnight (00:00) and 23 is 11 PM (23:00)
  0=do not re-split    1=eligible for re-split
  (IRESPLIT(24))                      Default:  Hour 17 = 1
  !  IRESPLIT = 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0 !

  Split is allowed only if last hour’s mixing
  height (m) exceeds a minimum value
  (ZISPLIT)                           Default: 100.      ! ZISPLIT = 100.0 !

  Split is allowed only if ratio of last hour’s
  mixing ht to the maximum mixing ht experienced
  by the puff is less than a maximum value (this
  postpones a split until a nocturnal layer develops)
  (ROLDMAX)                           Default: 0.25      ! ROLDMAX = 0.25 !


  HORIZONTAL SPLIT
  ----------------

  Number of puffs that result every time a puff
  is split - nsplith=5 means that 1 puff splits
  into 5
  (NSPLITH)                           Default:   5       ! NSPLITH =  5  !

  Minimum sigma-y (Grid Cells Units) of puff
  before it may be split
  (SYSPLITH)                          Default:  1.0      ! SYSPLITH = 1.0 !

  Minimum puff elongation rate (SYSPLITH/hr) due to
  wind shear, before it may be split
  (SHSPLITH)                          Default:  2.       ! SHSPLITH = 2.0 !

  Minimum concentration (g/m^3) of each
  species in puff before it may be split
  Enter array of NSPEC values; if a single value is
  entered, it will be used for ALL species
  (CNSPLITH)                          Default:  1.0E-07  ! CNSPLITH = 1.0E-07 !

Integration control variables ------------------------

  Fractional convergence criterion for numerical SLUG
  sampling integration
  (EPSSLUG)                           Default:   1.0e-04  ! EPSSLUG = 1.0E-04 !
```

```
      Fractional convergence criterion for numerical AREA
      source integration
      (EPSAREA)                          Default:   1.0e-06  ! EPSAREA = 1.0E-06 !

      Trajectory step-length (m) used for numerical rise
      integration
      (DSRISE)                           Default:   1.0      ! DSRISE = 1.0 !

!END!


--------------------------------------------------------------------------------


INPUT GROUPS: 13a, 13b, 13c, 13d -- Point source parameters
--------------------------------

---------------
Subgroup (13a)
---------------

     Number of point sources with
     parameters provided below      (NPT1)  No default  !  NPT1 =  11  !

     Units used for point source
     emissions below                (IPTU)  Default: 1  !  IPTU =   1  !
           1 =        g/s
           2 =       kg/hr
           3 =       lb/hr
           4 =     tons/yr
           5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
           6 =     Odour Unit * m**3/min
           7 =     metric tons/yr

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (13d)        (NSPT1) Default: 0  !  NSPT1 =  0  !

     Number of point sources with
     variable emission parameters
     provided in external file      (NPT2)  No default  !  NPT2 =  0  !

     (If NPT2 > 0, these point
     source emissions are read from
     the file: PTEMARB.DAT)

!END!

---------------
Subgroup (13b)
---------------
                                      a
          POINT SOURCE: CONSTANT DATA
          -----------------------------
                                                                              b          c
  Source      X UTM     Y UTM     Stack   Base     Stack    Exit  Exit    Bldg.  Emission
   No.     Coordinate Coordinate Height Elevation Diameter  Vel.  Temp.   Dwash   Rates
              (km)      (km)       (m)      (m)       (m)  (m/s) (deg. K)
  ------   ---------- ---------- ------  ------   -------- ----- -------- ----- --------
   1 ! SRCNAM = FLARE !
   1 ! X =    520.0,   5975.4,    59.5, 590.0,      1.27,  20.0, 1273.0,   .0, 1.2E02 !
   1 ! FMFAC  =      1.0 !   !END!
   2 ! SRCNAM = FH2O !
   2 ! X =    520.0,   5975.4,    16.2, 590.0,      1.22,   8.1,  695.0,   .0, 3.6E00 !
   2 ! FMFAC  =      1.0 !   !END!
   3 ! SRCNAM = FCCUR !
   3 ! X =    520.0,   5975.4,    38.4, 590.0,       .61,  26.9,  615.0,   .0,2.02E01 !
   3 ! FMFAC  =      1.0 !   !END!
   4 ! SRCNAM = NWINI !
   4 ! X =   520.25,   5981.0,    61.1, 596.0,       .61,  13.1, 1416.0,   .0, 1.8E01 !
   4 ! FMFAC  =      1.0 !   !END!
   5 ! SRCNAM = NWIS2 !
   5 ! X =   520.25,   5981.0,    61.1, 596.0,       .91,   6.5, 1044.0,   .0, 7.0E00 !
   5 ! FMFAC  =      1.0 !   !END!
   6 ! SRCNAM = PGRBI !
   6 ! X =    520.7,   5974.6,    61.0, 589.0,      3.96,  10.4,  423.0,   .0,3.0E-01 !
   6 ! FMFAC  =      1.0 !   !END!
   7 ! SRCNAM = PGRB2 !
   7 ! X =    520.7,   5974.6,    61.0, 589.0,      2.01,  17.9,  443.0,   .0, 9.7E00 !
   7 ! FMFAC  =      1.0 !   !END!
   8 ! SRCNAM = PGPB !
   8 ! X =    520.7,   5974.6,    56.1, 589.0,      2.18,  18.5,  438.0,   .0,3.05E01 !
   8 ! FMFAC  =      1.0 !   !END!
   9 ! SRCNAM = IPRB !
   9 ! X =    520.0,   5974.8,    76.4, 589.0,      4.27,  15.9,  467.0,   .0, 1.4E00 !
   9 ! FMFAC  =      1.0 !   !END!
  10 ! SRCNAM = IPPB !
  10 ! X =    520.0,   5974.8,    76.4, 589.0,      4.27,  15.9,  452.0,   .0,3.39E01 !
```

```
  10 ! FMFAC  =      1.0 !   !END!
  11 ! SRCNAM = SAP !
  11 ! X =    517.6,   5966.0,    30.4, 592.0,       1.2,   8.0,  330.0,   .0,7.12E00 !
  11 ! FMFAC  =      1.0 !   !END!

--------

    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

     SRCNAM  is a 12-character name for a source
             (No default)
     X       is an array holding the source data listed by the column headings
             (No default)
     SIGYZI  is an array holding the initial sigma-y and sigma-z (m)
             (Default: 0.,0.)
     FMFAC   is a vertical momentum flux factor (0. or 1.0) used to represent
             the effect of rain-caps or other physical configurations that
             reduce momentum rise associated with the actual exit velocity.
             (Default: 1.0  -- full momentum used)

    b
     0. = No building downwash modeled, 1. = downwash modeled
     NOTE: must be entered as a REAL number (i.e., with decimal point)

    c
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by IPTU
     (e.g. 1 for g/s).

---------------
Subgroup (13c)
---------------

           BUILDING DIMENSION DATA FOR SOURCES SUBJECT TO DOWNWASH
           -------------------------------------------------------
Source                                                                    a
 No.       Effective building width and height (in meters) every 10 degrees
------     ----------------------------------------------------------------


--------

    a
     Each pair of width and height values is treated as a separate input
     subgroup and therefore must end with an input group terminator.

---------------
Subgroup (13d)
---------------
                                               a
          POINT SOURCE: VARIABLE EMISSIONS DATA
          ---------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 13b.  Factors entered multiply the rates in 13b.
     Skip sources here that have constant emissions.  For more elaborate
     variation in source parameters, use PTEMARB.DAT and NPT2 > 0.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                              Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
           3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                    where first group is DEC-JAN-FEB)
           4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                    first group is Stability Class A,
                                    and the speed classes have upper
                                    bounds (m/s) defined in Group 12
           5 =       Temperature   (12 scaling factors, where temperature
                                    classes have upper bounds (C) of:
                                    0, 5, 10, 15, 20, 25, 30, 35, 40,
                                    45, 50, 50+)



--------
    a
     Data for each species are treated as a separate input subgroup
     and therefore must end with an input group terminator.


-------------------------------------------------------------------------------


INPUT GROUPS: 14a, 14b, 14c, 14d -- Area source parameters
```

```
--------------------------------

---------------
Subgroup (14a)
---------------

     Number of polygon area sources with
     parameters specified below (NAR1)       No default  !  NAR1 =  0   !

     Units used for area source
     emissions below            (IARU)       Default: 1  !  IARU =   1  !
           1 =        g/m**2/s
           2 =       kg/m**2/hr
           3 =       lb/m**2/hr
           4 =     tons/m**2/yr
           5 =     Odour Unit * m/s  (vol. flux/m**2 of odour compound)
           6 =     Odour Unit * m/min
           7 =     metric tons/m**2/yr

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (14d)        (NSAR1) Default: 0  !  NSAR1 =  0  !

     Number of buoyant polygon area sources
     with variable location and emission
     parameters (NAR2)                      No default  !  NAR2 =  0   !
     (If NAR2 > 0, ALL parameter data for
     these sources are read from the file: BAEMARB.DAT)

!END!

---------------
Subgroup (14b)
---------------
                                     a
          AREA SOURCE: CONSTANT DATA
          ----------------------------
                                                         b
Source           Effect.    Base      Initial    Emission
 No.             Height   Elevation   Sigma z     Rates
                   (m)       (m)        (m)
-------          ------    ------     --------   ---------


--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.
    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by IARU
     (e.g. 1 for g/m**2/s).

---------------
Subgroup (14c)
---------------

           COORDINATES (UTM-km) FOR EACH VERTEX(4) OF EACH POLYGON
           --------------------------------------------------------
Source                                                              a
 No.       Ordered list of X followed by list of Y, grouped by source
------     ------------------------------------------------------------


--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.


---------------
Subgroup (14d)
---------------
                                               a
          AREA SOURCE: VARIABLE EMISSIONS DATA
          --------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 14b.  Factors entered multiply the rates in 14b.
     Skip sources here that have constant emissions.  For more elaborate
     variation in source parameters, use BAEMARB.DAT and NAR2 > 0.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                               Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
```

```
          3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                   where first group is DEC-JAN-FEB)
          4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                   first group is Stability Class A,
                                   and the speed classes have upper
                                   bounds (m/s) defined in Group 12
          5 =       Temperature   (12 scaling factors, where temperature
                                   classes have upper bounds (C) of:
                                   0, 5, 10, 15, 20, 25, 30, 35, 40,
                                   45, 50, 50+)


--------
    a
     Data for each species are treated as a separate input subgroup
     and therefore must end with an input group terminator.


-------------------------------------------------------------------------------

INPUT GROUPS: 15a, 15b, 15c -- Line source parameters
---------------------------

---------------
Subgroup (15a)
---------------

     Number of buoyant line sources
     with variable location and emission
     parameters (NLN2)                           No default  !  NLN2 =  0   !

     (If NLN2 > 0, ALL parameter data for
      these sources are read from the file: LNEMARB.DAT)

     Number of buoyant line sources (NLINES)       No default   ! NLINES =  0  !

     Units used for line source
     emissions below               (ILNU)          Default: 1  !  ILNU =   1  !
           1 =        g/s
           2 =       kg/hr
           3 =       lb/hr
           4 =     tons/yr
           5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
           6 =     Odour Unit * m**3/min
           7 =     metric tons/yr

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (15c)        (NSLN1) Default: 0  !  NSLN1 =  0  !

     Maximum number of segments used to model
     each line (MXNSEG)                            Default: 7   ! MXNSEG =  7  !

     The following variables are required only if NLINES > 0.  They are
     used in the buoyant line source plume rise calculations.

        Number of distances at which               Default: 6   ! NLRISE =  6  !
        transitional rise is computed

        Average building length (XL)               No default   ! XL = .0 !
                                                   (in meters)

        Average building height (HBL)              No default   ! HBL = .0 !
                                                   (in meters)

        Average building width (WBL)               No default   ! WBL = .0 !
                                                   (in meters)

        Average line source width (WML)            No default   ! WML = .0 !
                                                   (in meters)

        Average separation between buildings (DXL)  No default   ! DXL = .0 !
                                                   (in meters)

        Average buoyancy parameter (FPRIMEL)       No default   ! FPRIMEL = .0 !
                                                   (in m**4/s**3)

!END!

---------------
Subgroup (15b)
---------------

          BUOYANT LINE SOURCE: CONSTANT DATA
          ----------------------------------
                                                                                a
Source     Beg. X      Beg. Y      End. X    End. Y     Release    Base        Emission
```

```
 No.     Coordinate  Coordinate  Coordinate Coordinate  Height    Elevation      Rates
            (km)        (km)        (km)       (km)       (m)        (m)
------   ----------  ----------  ---------  ----------  -------   ---------    ---------

--------

    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by ILNTU
     (e.g. 1 for g/s).

---------------
Subgroup (15c)
---------------
                                                       a
          BUOYANT LINE SOURCE: VARIABLE EMISSIONS DATA
          ----------------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 15b.  Factors entered multiply the rates in 15b.
     Skip sources here that have constant emissions.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                                Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
           3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                    where first group is DEC-JAN-FEB)
           4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                    first group is Stability Class A,
                                    and the speed classes have upper
                                    bounds (m/s) defined in Group 12
           5 =       Temperature   (12 scaling factors, where temperature
                                    classes have upper bounds (C) of:
                                    0, 5, 10, 15, 20, 25, 30, 35, 40,
                                    45, 50, 50+)



--------
    a
     Data for each species are treated as a separate input subgroup
     and therefore must end with an input group terminator.


-------------------------------------------------------------------------------


INPUT GROUPS: 16a, 16b, 16c -- Volume source parameters
---------------------------

---------------
Subgroup (16a)
---------------

     Number of volume sources with
     parameters provided in 16b,c (NVL1)     No default  !  NVL1 =  0   !

     Units used for volume source
     emissions below in 16b       (IVLU)     Default: 1  !  IVLU =   1  !
           1 =        g/s
           2 =       kg/hr
           3 =       lb/hr
           4 =     tons/yr
           5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
           6 =     Odour Unit * m**3/min
           7 =     metric tons/yr

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (16c)      (NSVL1)    Default: 0  !  NSVL1 =  0  !

     Number of volume sources with
     variable location and emission
     parameters                   (NVL2)     No default  !  NVL2 =   0   !

     (If NVL2 > 0, ALL parameter data for
      these sources are read from the VOLEMARB.DAT file(s) )

!END!

---------------
```

```
Subgroup (16b)
--------------
                                        a
           VOLUME SOURCE: CONSTANT DATA
           ------------------------------
                                                                             b
         X UTM      Y UTM      Effect.    Base     Initial    Initial    Emission
     Coordinate  Coordinate   Height   Elevation  Sigma y    Sigma z     Rates
        (km)       (km)        (m)       (m)        (m)        (m)
     ----------  ----------   ------    ------    --------   --------   --------


--------
    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by IVLU
     (e.g. 1 for g/s).

--------------
Subgroup (16c)
--------------
                                                 a
          VOLUME SOURCE: VARIABLE EMISSIONS DATA
          ----------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 16b.  Factors entered multiply the rates in 16b.
     Skip sources here that have constant emissions.  For more elaborate
     variation in source parameters, use VOLEMARB.DAT and NVL2 > 0.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                          Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
           3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                    where first group is DEC-JAN-FEB)
           4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                    first group is Stability Class A,
                                    and the speed classes have upper
                                    bounds (m/s) defined in Group 12
           5 =       Temperature   (12 scaling factors, where temperature
                                    classes have upper bounds (C) of:
                                    0, 5, 10, 15, 20, 25, 30, 35, 40,
                                    45, 50, 50+)



--------
    a
     Data for each species are treated as a separate input subgroup
     and therefore must end with an input group terminator.


-------------------------------------------------------------------------------

INPUT GROUPS: 17a & 17b -- Non-gridded (discrete) receptor information
-----------------------

--------------
Subgroup (17a)
--------------

     Number of non-gridded receptors (NREC)  No default  !  NREC =  10   !

!END!

--------------
Subgroup (17b)
--------------
                                                a
           NON-GRIDDED (DISCRETE) RECEPTOR DATA
           ------------------------------------

                  X UTM       Y UTM       Ground        Height   b
Receptor       Coordinate  Coordinate    Elevation   Above Ground
  No.            (km)        (km)          (m)           (m)
--------       ----------  ----------    ---------   ------------
     1 ! X =       517.0,   5973.975,     570.000,      30.000!   !END!
     2 ! X =     519.163,   5973.362,     625.000,      10.000!   !END!
     3 ! X =     515.621,   5967.786,     620.000,      10.000!   !END!
     4 ! X =     519.437,    5972.68,     720.000,      10.000!   !END!
     5 ! X =       517.5,     5974.5,     570.000,      30.000!   !END!
     6 ! X =       517.0,     5974.5,     570.000,      30.000!   !END!
```

```
    7 ! X =       516.5,     5974.0,     570.000,      30.000!   !END!
    8 ! X =       516.5,     5974.5,     570.000,      30.000!   !END!
    9 ! X =       516.5,     5973.5,     570.000,      30.000!   !END!
   10 ! X =       517.5,     5973.5,     570.000,      30.000!   !END!
```

----

[a] Data for each receptor are treated as a separate input subgroup and therefore must end with an input group terminator.

[b] Receptor height above ground is optional. If no value is entered, the receptor is placed on the ground.

GLOSSARY OF TERMS

Air Quality Episode A period of time during which a pollutant concentration exceeds a level considered safe.

Albedo (solar) Reflectivity of a surface.

AQM Air Quality Model.

Boundary Layer The bottom layer of the atmosphere that experiences the direct effects of the Earth’s surface. It ranges from as shallow as 100 m on a calm, cold night to a depth of 1 km or more in a warm, daytime situation.

CALMET California Meteorology model. A meteorological model that develops hourly wind and temperature fields on a three-dimensional gridded modelling domain, along with associated two-dimensional fields.

CALPUFF California Puff model. A transport and dispersion model that advects ‘puffs’ of material emitted from modelled sources.

CTDM Complex Terrain Dispersion Model.

Deterministic Interpolates or extrapolates from a dataset using empirical constructs.

Dispersion Model A computer model that predicts pollutant concentrations by using emission and meteorological data.

Fumigation A process where pollutants at higher elevations are brought down to the surface when daytime heating removes the inversion layer and causes mixing.

Gaussian Plume Model A dispersion model that treats effluent as a continuous plume that is governed by Gaussian statistics.

GLC Ground Level Concentration.

Grid Cell A volume of surrounding air that contains averaged values. Many grid cells together make up a modelling domain.

Inversion A layer of warmer air above a cooler one, suppressing vertical motion within the cool layer.

ISC Industrial Source Complex. A Gaussian Plume dispersion model.

Katabatic Wind Any wind blowing downslope. Usually cold.

Lapse Rate The rate at which an atmospheric variable (usually temperature) decreases with height.

Mesoscale Model An atmospheric computer model able to resolve circulations from roughly 100 m to 1 000 km in scale.

Meteorological Model A computer model that constructs fields of wind, temperature, humidity etc. using meteorological data.

MM5 Mesoscale Model 5.

MRE Mean Relative Error.

NCEP National Centers for Environmental Prediction. A source of the gridded meteorological fields used to initialize a mesoscale model.

Numerical Instability Describes a situation where a numerical solution produced by a prognostic computer model rapidly diverges from the true solution.

Prognostic (A computer model) able to predict a future state of a variable or variables.

Radiosonde An instrument attached to a balloon that measures and transmits values of pressure, temperature and humidity as it ascends through the atmosphere. Tracking the motion of the sonde allows determination of the horizontal wind.

RAMS Regional Atmospheric Modeling System.

Regulatory Model A (dispersion) model that is accepted by a governing body and is used to make planning decisions.

RMSVE Root Mean Square Vector Error.

Soil Heat Flux The rate of the sum of energy contributions from the soil to the air above.

Surface Roughness A value to represent the drag a type of surface or vegetation has on the wind.

Vegetation Leaf Area Index A value to represent the effect a type of vegetation has on energy and moisture budgets.

Windrose diagram A wind diagram that shows wind direction and the frequency that the wind was from that direction for a location. Wind speed is also indicated.