Use of High Resolution Numerical Fields with the CALPUFF Modelling System: An Analysis of RAMS and MC2 Fields Over Kamloops, B.C.

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1.0 Executive Summary

This report presents an analysis of high resolution mesoscale model fields, with a particular focus on assessing the application of these fields within a regulatory dispersion modelling framework. Output fields from the Regional Atmospheric Modeling System (RAMS) and the Mesoscale Compressible Community (MC2) model were used with the CALPUFF modelling system over Kamloops, British Columbia. Specifically, a number of different methodologies for applying the prognostic fields to drive the CALPUFF meteorological processor (CALMET) were examined. The resulting prognostic-derived CALMET meteorological fields were compared to station observations and a ‘benchmark’ CALMET run that used station data alone. The comparisons highlight those parameters known to have a significant effect on the dispersion of airborne pollutants.

The assessment was performed for a two-week winter period utilizing RAMS and MC2 output from two earlier studies initiated by the B.C. Ministry of Water, Land and Air Protection. Although these earlier works included validation of the mesoscale fields, the methodologies and datasets used in the validation differed between the two studies. This study allowed for an analysis of the prognostic fields within a common framework, in addition to a comparison with deterministic (CALMET) fields. The two-week period experienced high pressure, light wind conditions, typical of the synoptic patterns associated with relatively poor air quality in the region. As such, the comparisons here are relevant to stagnant conditions, which are very challenging to simulate for any meteorological model. These results may not be representative of other synoptic situations.

The CALMET meteorological runs included both ‘no obs’ runs (without the use of any local meteorological observations) and runs utilizing a combination of surface station data and mesoscale model fields. CALMET was configured to operate with the following 5 run scenarios:

1) Use of all surface observation stations in the domain (5) and upper-air data from Kelowna;
2) Use of all surface observation stations in the domain (5) and prognostic/mesoscale upper air fields;
3) Use of prognostic/mesoscale fields without additional adjustment from CALMET routines;
4) Use of prognostic/mesoscale fields with adjustment from the CALMET Diagnostic Wind Module; and,
5) Use of ‘pseudo-stations’ constructed directly from prognostic/mesoscale fields.

Scenarios 2-5 were performed separately for both the RAMS and MC2 fields.

In general, the ‘no obs’ CALMET runs using each prognostic dataset were successful at simulating both surface and upper-air winds. The RAMS-derived CALMET runs were more successful at predicting surface winds in the valley than the MC2-derived runs, likely due to the higher resolution of the RAMS simulation (1 km grid spacing as compared to 2 km spacing of MC2). Outside of the valley locations, the MC2-derived runs achieved better comparisons with observed surface wind directions than the RAMS-derived runs. The internal CALMET adjustments from its Diagnostic Wind Module did not improve resultant wind predictions and were found to have little effect on the high resolution prognostic input. In addition, the pseudo-station methodology for use of mesoscale fields with CALMET was found to be problematic and is not recommended over the use of the full mesoscale fields in ‘no obs’ mode.

Prognostic-derived cloud cover, as calculated by CALMET, was found to be significantly different than observations at Kamloops. The current version of CALMET calculates cloud cover fractions directly from the 850 mb relative humidity field. This algorithm likely does not resolve low level cloud accurately, even if a mesoscale model is able to develop the feature. An alternative approach is to specify cloud cover fractions in an external file, which CALMET can use instead of the estimated parameters. Further investigation of this issue is suggested.

Surface temperature, and near-surface vertical temperature gradients from the prognostic-derived CALMET runs were also determined. In this regard, CALMET runs using MC2 and RAMS input were significantly different. The vertical profiles determined from RAMS represented weaker near-surface stability in the mornings, and the MC2 profiles represented stronger stability in the afternoons, compared to profiles determined with radiosonde data. The MC2-derived runs also clearly had a cold bias in surface temperatures, which the RAMS-derived runs did not exhibit.

Prognostic-derived CALMET mixing heights and Pasquill-Gifford (PG) classes were compared with benchmark values determined from station data. The ‘no obs’ CALMET values were significantly different than the benchmark values. CALMET runs using a combination of surface station data and prognostic fields produced identical PG classes and only moderately different mixing heights compared with the benchmark run. This suggests that it is primarily the cloud cover differences between prognostic-derived and deterministic meteorology that lead to different CALMET stability parameters. An improved CALMET algorithm for determining cloud cover may decrease this difference in the future. Currently, the methodology of combining surface data and mesoscale upper-air fields has a strong potential to increase the accuracy of a dispersion simulation. The actual effect that prognostic-derived CALMET fields have on CALPUFF dispersion estimates remains to be investigated.

The strengths and weaknesses determined in the mesoscale fields for the two-week period of the study imply that numerical simulations can be a highly useful source of data for regulatory dispersion modelling, although modelling outcomes may substantially differ depending on the mesoscale model (and choice of mesoscale model options) used. Some initial analysis of the boundary layer characteristics of a mesoscale simulation would help select a model, or modelling configuration that adequately characterises a region of interest.

1.0 Introduction

A regulatory dispersion model predicts ambient air concentrations due to source(s) of air contaminants. To do this, a contemporary dispersion model, such as the California Puff Model (CALPUFF), requires 3D fields of wind and temperature. Typically, these fields are constructed with a deterministic processor that extrapolates surface and upper-air station data collected in or near the area of interest. The quality of meteorological fields produced in this manner depends on the complexity of terrain and the number and quality of meteorological stations near the emission sources. An alternative approach is to use the simulated meteorological fields from a prognostic mesoscale model. Mesoscale models, commonly referred to as weather forecasting models, use numerical techniques to solve the analytical equations governing atmospheric motions. These models are now able to simulate local temperature and winds at high resolution without the prohibitively large computer run times that until recently made such application unrealistic. This work is the first part of a potentially two part study that assesses the use of prognostic model fields in regulatory dispersion modelling.

All necessary meteorological parameters for dispersion modelling can be acquired from one of several available mesoscale models, in lieu of collecting meteorological station data. In some areas, high resolution mesoscale model fields are produced operationally, and can be obtained for little, and sometimes no cost. Validation of the model fields has provided some indication of accuracy, typically on an hour by hour basis. Predictions of temperature, wind, and other related variables can at times be significantly different than actual observations show. However, regulatory dispersion modelling is generally used for predicting maximum and average pollutant concentrations over long periods of time (usually a year). For the purposes of regulatory modelling, a more important issue may be not hour-by-hour differences in modelled versus actual meteorology, but whether or not a prognostic model can generate the range of atmospheric conditions experienced in an area. What actual differences result from the use of prognostic fields in dispersion analyses compared to the typical use of station observations is of additional interest.

In this study, the application of mesoscale fields with the CALPUFF dispersion model is analysed. Two earlier (2003) British Columbia Ministry of Water, Land and Air Protection (WLAP) sponsored modelling studies, *Hind-casting of High Resolution Atmospheric Fields over Complex Terrain: Model Initialization Issues (WAC-03-220)* and *South-Central B.C. Air Quality Ensemble Research*, produced high resolution prognostic meteorological fields over the Thomson-Okanagan region. The analysis of the fields showed that there is potential for the use of such prognostic 'data' in air quality studies, but both projects identified some concerns with the use of the meteorological fields for air dispersion modelling. The issue of the applicability of prognostic fields to regulatory dispersion modelling was also considered in the discussion paper

Using Mesoscale Modeling to Support Regulatory Dispersion Modeling completed for WLAP in 2002.

Due to a lack of observation stations in some areas, there is interest in the use of simulated meteorological fields in British Columbia, primarily in the north of the province. In addition, many areas of interest are situated in complex terrain that would require several observation stations to adequately characterize circulation near the surface. For these situations, establishing surface (and potentially upper-air) observation stations and collecting data represents a considerable investment in both time and money. With the common availability of higher speed computers, it is now much more feasible to use prognostic models to produce high resolution meteorological fields for the long periods needed to adequately characterize the climatology of a geographic area. The models utilize the network of existing observation stations throughout North America. By telescoping or ‘nesting’ down to smaller areas, a prognostic model can simulate circulation patterns without the use of any local station data. Whether existing models can adequately simulate boundary layer features, such as 3-dimensional temperature structure, is a question of considerable importance.

1.1 THE CALPUFF MODELLING SYSTEM

CALPUFF is a non-steady-state air quality modelling system that was developed by Sigma Research Corporation through sponsorship from the California Air Resources Board (CARB). The project goal was to develop a complete modelling package for regulatory use, while reflecting the current understanding of air dispersion. The dispersion model (CALPUFF) is a transport and dispersion model that advects ‘puffs’ of material released from modelled sources. As opposed to earlier gaussian plume models, CALPUFF is a lagrangian model that requires 3-dimensional fields of wind and temperature, along with associated 2-dimensional fields such as mixing heights, surface characteristics and dispersion properties. To develop these fields, a deterministic meteorological processor (CALMET) was created. CALMET requires both hourly surface and twice-daily upper-air data to construct the meteorological fields. CALMET cannot forecast meteorology, but has a Diagnostic Wind Module (DWM) that adjusts wind and temperature fields due to the influence of terrain and vegetation. There are several ‘switches’ in the CALMET model that must be set by the modeller to reflect the unique geophysical characteristics within an airshed. The first version of the CALPUFF modelling system was released in 1990, which included CALPUFF, CALMET and CALPOST (a post-processor for analysis of modelling results).

Later model versions included improvements in model dynamics and the option to use MM4 (Penn State Mesoscale Model) or MM5 gridded meteorological fields to supplement observations. Recent model versions of CALMET (5.5 and up) are more sophisticated, allowing the user a significant amount of control over the parameters influencing the 3D wind and temperature fields, including the merger of prognostic and observational data. CALMET now has the ability to construct meteorological fields without the use of any observations, called '*no obs*' mode. In many cases, use of the CALMET processor actually requires more attention and operator experience than the CALPUFF dispersion model itself.

1.2 POTENTIAL ROLE OF MESOSCALE MODELS IN REGULATORY DISPERSION MODELLING

Mesoscale model fields have been used with regulatory dispersion models, in particular CALPUFF, to determine near-field impacts of pollutant sources. With the CALPUFF model, typical use of the prognostic data has been to apply the coarser-resolution wind field as an 'initial guess' to the upper air flow. Following this step, CALMET blends the initial wind field with surface observations. Studies claim that this approach can lead to better air quality simulations than with the use of meteorological station observations alone. Although there is still a scarcity of published work on the use of prognostic data in regulatory dispersion modelling, some guidance is available regarding this modelling strategy from the U.S. Environmental Protection Agency (EPA) sponsored CALPUFF website[1]. Some pertinent comments include the following (bracketed comments added by the authors):

- Due to a sparsity of upper-air observations, CALMET may not capture significant mesoscale circulations such as land-sea interactions (and thus would benefit from prognostic fields).
- The use of MM4 or MM5 as initial guess field with NWS observation data has produced at least as good, and often better results than just using NWS data alone.
- Preliminary tests of using mesoscale model data alone to drive the entire CALMET analysis have not provided consistent results and is thus considered the least desirable approach.
- Poorly characterized (mesoscale model) data may adversely affect dispersion model results.

Although there have been several regulatory dispersion modelling studies that have utilized mesoscale data (in British Columbia and elsewhere), in most cases the work has involved the use of coarse resolution prognostic fields (i.e., on the order of 20 km horizontal resolution, 100m vertical resolution). In these studies, the prognostic fields were applied in a limited way, to represent the upper air flow. Surface wind fields (and other meteorological variables) were derived from station observations. Access to higher resolution mesoscale model fields was limited because of the significant computer resources (and operator skill) required to generate them.

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[1] U.S. EPA Support Center for Regulatory Air Models (SCRAM) links to an Earth Tech site which lists 'Frequently Asked Questions' which discusses the latest developments of the model, and user's observations (http://www.src.com/calpuff/calpuff1.htm).

Simulated meteorology has the potential to replace the use of meteorological observations in regulatory dispersion modelling, particularly for areas with limited meteorological observations. However, there have been deficiencies noted in the prognostic fields at certain times and meteorological conditions. Most notably, mesoscale models appear to have difficulty simulating boundary layer fields in regions of complex terrain, even when using relatively high horizontal and vertical grid spacing.

CALMET has the capability to run in a '*no obs*' mode, where the required meteorological and micro-meteorological input parameters are derived from prognostic model fields, instead of observations. Another approach for the exclusive use of prognostic fields in CALMET has been the creation of simulated, or 'pseudo' station data. With the latter method, some operator control is retained over what information CALMET receives. This can be necessary at times due to the limitations in the horizontal resolution of mesoscale model simulations. Both approaches have the option of adjusting the winds in the lowest layers with CALMET's Diagnostic Wind Module (DWM). DWM adjusts the initial wind field for the fine scale effects of complex terrain. Slope flows (drainage) are parameterized, along with thermodynamic blocking effects. Following this, vertical velocity is adjusted, and a divergence minimization procedure is applied to the horizontal winds[2].

With the current access to sophisticated numerical tools and model output, the ease of applying prognostic meteorology to dispersion modelling has greatly increased. There remains the need to develop a greater understanding of the ramifications of using numerical fields in regulatory air quality studies in both B.C. and elsewhere. Experience gained by applying prognostic data in the CALPUFF modelling system is directly applicable to other dispersion models, including future models that may have this kind of capability within a simplified procedure.

1.3 STUDY OBJECTIVES

The Regional Atmospheric Modeling System (RAMS) and the Mesoscale Compressible Community (MC2) mesoscale models were used to produce two-week meteorological simulations over the Thomson-Okanagan region for summer, 2002 and winter, 2003. Each interval was representative of brief ('episodic') periods during which high levels of ground-level ozone or particulate matter were measured. The meteorological simulations were an attempt to represent the ambient conditions that can lead to problematic air quality in the Thomson-Okanagan. Output fields from the winter simulations were obtained and formatted for use with the CALPUFF meteorological processor (CALMET).

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[2] A User's Guide for the CALMET Meteorological Model, http://www.src.com/calpuff/calpuff1.htm.

The purpose of this work is to analyze the different options available for using numerical (mesoscale model) fields with the CALPUFF dispersion model in regions of complex terrain. A comparison is made between CALMET meteorological fields using the following datasets as input to the model:

- Surface and upper-air observation data
- Surface observation data with RAMS numerical fields for upper-air conditions
- Surface observation data with MC2 numerical fields for upper-air conditions
- RAMS numerical fields alone
- MC2 numerical fields alone
- RAMS generated pseudo-station data
- MC2 generated pseudo-station data

The assessment focuses on the meteorological parameters that potentially have a large impact on the dispersion of airborne pollutants. It is expected that the results of this assessment will provide guidance towards a suitable modelling approach that can be used in situations where either a lack of observation data exists (e.g., in regions of Northern British Columbia) or when high resolution numerical data is available in addition to observations. A further study using the CALMET meteorological fields for idealized CALPUFF dispersion modelling may occur in a future study.

1.4 ASSESSMENT APPROACH

The simulated meteorological fields from the RAMS model and the MC2 model represent a volume of space over South-Central B.C. The sizeable communities in this region are Kelowna and Kamloops. Although there is an upper-air station in Kelowna, the modelling domain for this study is centered over Kamloops. The primary reason for the selection of the Kamloops area is that it better represents an ‘average’ airshed in B.C., with an upper air station somewhat removed from the actual modelling domain.

In the discussion below, a distinction is made between modelled meteorological fields produced by CALMET using prognostic ‘data’ and modelled meteorological fields produced by using surface and upper air observations (i.e., the manner that CALPUFF is commonly used for near-field studies). ‘Prognostic-derived’ fields describe the former, whereas ‘deterministic’ fields describe the latter. Both prognostic-derived and deterministic surface wind fields were validated in this study with surface observations. Also, a ‘benchmark’ CALMET run was conducted that used the Kelowna upper air station and all available surface stations. The meteorological fields from this run serve as a standard against which the prognostic-derived CALMET runs are assessed.

Previous mesoscale modelling studies have provided a measure of the statistical error in numerical meteorological fields in different situations. However, similar analyses generally have not been conducted for CALMET fields when initialized by surface and upper air observations. An analysis of CALMET deterministic fields is required before a measure of how ‘skillful’ or how ‘different’ prognostic-derived meteorology is when compared to deterministic fields. Analysis of the surface wind fields can be achieved by comparing modelled winds to observed winds from a station or stations that were not used to drive CALMET. A series of CALMET deterministic runs were conducted by systematically removing one station from the initialization dataset. Each CALMET run was then used for a wind validation at the removed station location. In this way, identical validation was performed on the deterministic fields as on the prognostic-derived fields. The surface wind validation provides assessment of the different CALMET ‘*no obs*’ modelling approaches, as well as an indication of the magnitude of error associated with a typical (deterministic) CALMET run.

Upper air validation was more difficult to achieve in this study. Radiosonde data is available in the form of a vertical profile every 12 hours. A measure of the error in the upper air prognostic fields was determined during the earlier WLAP-sponsored research. In terms of upper air, this study addresses how ‘different’ the prognostic-derived fields are from the deterministic fields. This is achieved by comparing prognostic-derived CALMET variables such as wind speed, wind direction and mixing height to the benchmark deterministic CALMET values. Trend analysis is also used to support the quantitative assessments.

2.0 Mesoscale Simulations

Only a brief description of the two mesoscale simulations is provided here. The RAMS simulation was conducted by one of the authors of this study, in consultation with Dr. Peter Jackson, using the High Performance Computing (HPC) facility at the University of Northern British Columbia (UNBC). The MC2 simulation was conducted at the University of British Columbia (UBC) under the supervision of Dr. Roland Stull. A full account of the earlier work can be found in the WLAP documents *Hind Casting of High Resolution Atmospheric Fields Over Complex Terrain: Model Initialization Issues* (WAC-03-220) and *South Central B.C. Air Quality Ensemble Forecast Research, A Final Grant Report to the BC Ministry of Water, Land and Air Protection (WLAP).*

Each simulation study used 90-km fields from the Eta model for initialization and nudging. Nudging uses a relaxation scheme to force model predictions to approach the values of observed features in the large scale fields at regular time intervals. The Eta model, supported by the U.S. National Centers for Environmental Prediction (NCEP), is continuously run over a large domain including North America, and output is available as both *analyzed* and *forecast* fields. The objective analysis system in the model constructs the analyzed fields every 6 hours from a network of available meteorological observations. These fields are dynamically balanced and as such do not necessarily match observations at a single point. The Eta model is initialized with the 0Z (UTC) analysis fields each morning and produces forecasts that are output in 3-hourly intervals. The 6-hourly analysis fields and the 3-hourly forecast fields are available from the U.S. National Weather Service website[3].

The Eta model is designed to simulate larger, regional-scale circulation patterns that are used as weather forecast products. The output fields have additional benefit in that they can be used as input to higher resolution mesoscale models, which in turn produce local circulations. The RAMS simulation used in this study is actually a 'hindcast' because it uses the Eta 6-hourly analysis fields for nudging, and simulates a period of time in the past. The MC2 simulation is a forecast because it uses the 3-hourly Eta forecast fields for nudging, producing a simulation of meteorological fields in the future. The RAMS simulation was initiated and conducted strictly for the period of interest, whereas the MC2 simulation was an extension of the existing operational forecasting program at UBC.

The two-week period in winter, 2003 was dominated by a broad high-pressure system that persisted for most of the interval[4]. As such, regional winds were generally light, and local

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[3] http://www.nws.noaa.gov/tg/modfiles.html

[4] Stull, R., 2003. *South Central B.C. Air Quality Ensemble Forecast Research, A Final Grant Report to the BC Ministry of Water, Land and Air Protection (WLAP).*

terrain-induced circulation patterns were responsible for much of the variability in near-surface winds. Both RAMS and MC2 used a series of nested domains to sequentially resolve smaller-scale motions. From the synoptic scale weather patterns represented in the outer domain, RAMS nested down to an inner domain with 1 km horizontal resolution. Similarly, MC2 had an inner domain with a 2 km horizontal resolution.

Each of the two simulations had weaknesses when compared to local observations. As discussed in the two earlier studies, the weaknesses include, but are not limited to, the following:

- RAMS: surface-based inversions were generally not well represented. Strong nocturnal stability was modelled as either slightly stable or neutral
- MC2: cold bias in temperatures near the surface and a warm bias in upper-air temperatures

The two analyses used different validation methodologies and cannot easily be compared on the basis of the corresponding reports. In addition, each validation scheme used data from many surface stations in the area; some of which do not have the same level of maintenance and data assurance as others.

3.0 Methodology: CALMET Modelling Scenarios

Mesoscale simulations have been used to provide upper-air data for dispersion analyses in situations where representative radiosonde data could not be acquired. With the CALPUFF system, the upper-air fields are generally used in conjunction with local surface station data as inputs the CALMET meteorological processor. In some situations, numerical data have been used to create ‘pseudo-stations’ by extracting data from the meteorological fields and formatting them to match the station data configuration. In recent CALMET model versions (5.5 and up), the option to run the model without the use of any observation data, called ‘no obs’ mode, can be selected. In this mode, CALMET uses the full mesoscale fields to derive its own (typically higher resolution) deterministic meteorological fields. CALMET is able to treat the simulated data as either observations or as initial guess fields that are subsequently adjusted by considering topographical influences. The RAMS and MC2 simulations were

The Kamloops Modelling domain and the locations of 5 surface observation stations selected for this study are shown in Figure 3.1. The location of the nearest upper-air observation station (Kelowna) is approximately 100 km SSE of Kamloops. The 5 surface meteorological stations were chosen from a larger number of existing stations within the region. Although there are 4 Ministry of Forests (MoF) wind stations in the modelling domain, none were used. Analysis of the MoF stations showed a very high percentage of calms (zero wind speeds) during the two week period; in addition, it is known that these stations are not maintained over the winter months. Finally, pictures were not available of the stations, so verification of appropriate siting could not be done. Data from two City of Kamloops surface wind stations were used. The city provided the data, information on the type of instruments used, and pictures of the meteorological towers. It was determined that the stations were well sited, and wind rose diagrams were a reasonable match to what was expected, considering nearby topographical influences. The data for the two Kamloops stations were provided with observations approximately every 10 minutes. The 10-minute values were used to calculate an hour-average scalar mean wind speed and vector wind direction for each hour of the two-week period, since this is required by CALMET. Data for the Environment Canada (EC), WLAP and Ministry of Transportation and Highways (MoTH) surface stations were available as hour averaged values. A summary of the 5 surface stations is provided in Table 3.1.

Figure 3.1: CALMET Modelling Domain with Surface Station Locations

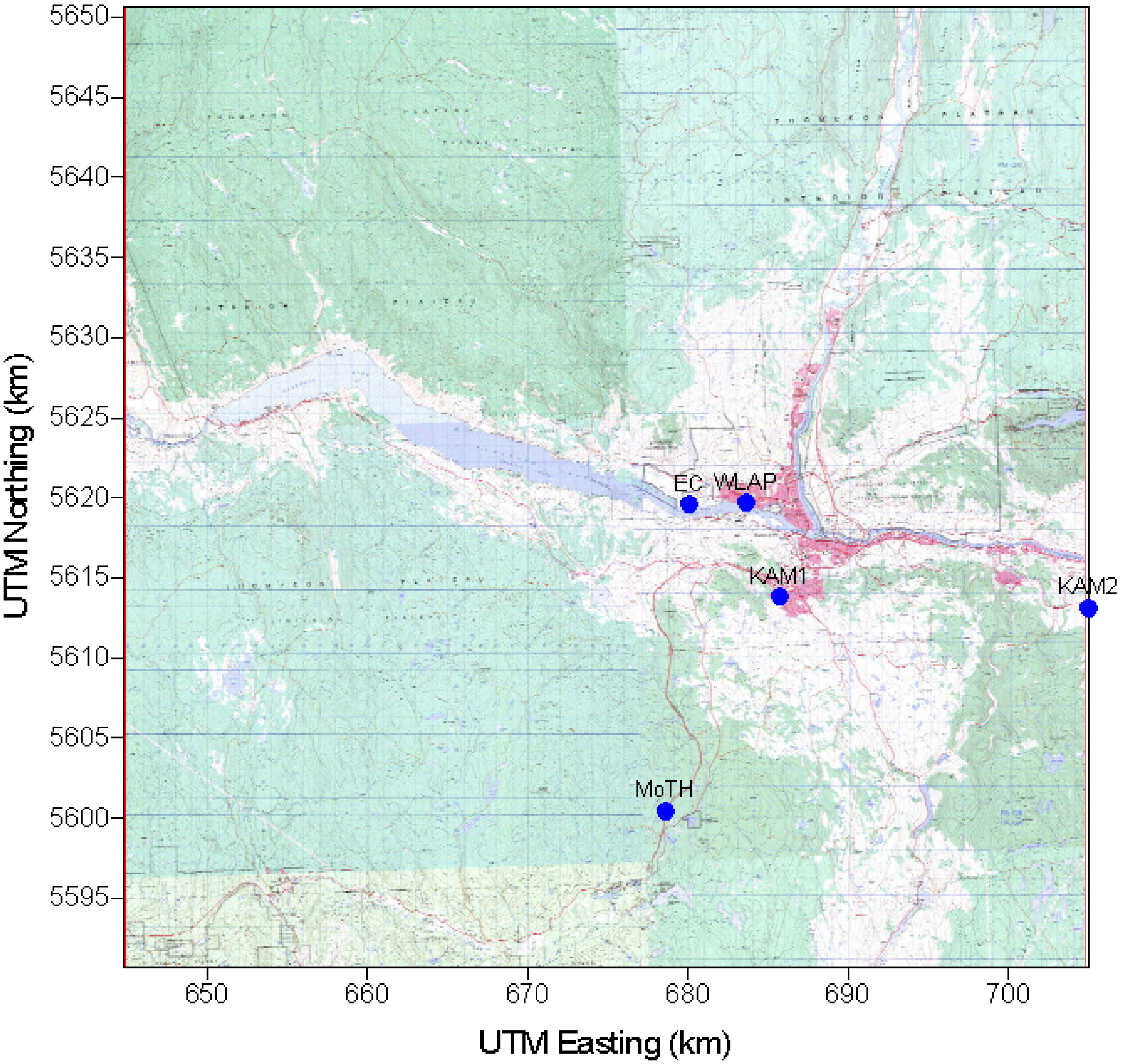

Table 3.1: Surface Observation Station Locations

Surface Station	**Location**		
	Description	**UTM E (km)**	**UTM N (km)**
EC YKA (3780)	Kamloops Airport	680.072	5619.566
WLAP Brocklehurst	Kamloops city, 3.5 km E of Kamloops Airport	683.603	5619.689
MoTH Walloper	Coquihalla Highway, SSW of Kamloops	678.601	5600.482
Kam1	Pacific Way, southern edge of Kamloops	685.749	5613.792
Kam2	Barnhartvale Road, 15km E of Kamloops	704.993	5613.106

CALMET has a number of options or ‘switches’ that must be set before a meteorological run commences. Some of the switches have default values that indicate an appropriate choice in most situations. Others do not have default values, and the setting of these switches depends on characteristics of the modelling domain and availability of data. Of additional interest, the CALMET atmospheric levels, or layers, were set to a higher number than is commonly used, in part to facilitate comparison with observations. A description of the CALMET levels is shown in Table 3.2. A summary of the switches used for the CALMET runs is provided in Table 3.3. All CALMET options chosen are shown in the example input file in Appendix B. A few changes in CALMET options were made for the runs using prognostic data; these are described in the following sections.

Table 3.2: CALMET Levels

CALMET Level	Thickness (m)	Mid-point (m)
1	0 – 20	10
2	20 – 50	35
3	50 – 100	75
4	100 – 200	150
5	200 – 300	250
6	300 – 400	350
7	400 – 500	450
8	500 – 800	650
9	800 – 1000	900
10	1000 – 1500	1250
11	1500 – 2000	1750
12	2000 – 3300	2650

Table 3.3: Significant CALMET Options

Option	Setting
ZFACE (number of atmospheric layers)	12
IEXTRP (extrapolation of surface winds)	1 (no extrapolation)
LVARY (vary radius of influence of obs stations)	T (true)
RMAX1 (station influence parameter)	5 km
RMAX2 (station influence parameter)	5 km
RMAX3 (station influence parameter)	10 km
TERRAD (influence of terrain features)	10 km
R1 (station influence parameter)	3 km
R2 (station influence parameter)	50 km

3.1 CALMET MODELLING USING OBSERVATION DATA

Two of the 5 surface observation stations used in this study have anemometers with relatively high stall speeds. The EC and MoTH stations both have a threshold speed of 1 m/s, meaning that wind speeds below this magnitude are registered as zero. To ensure CALMET was not adversely affected by the zero speeds, all zero wind speeds were flagged to indicate missing values instead. This involved 50% of the hourly EC winds and 26% of the MoTH winds during the two week period.

A CALMET run was conducted using all 5 surface meteorological stations and one upper-air station. This simulation is referred to as the *'BENCHMARK'*. Due to the valley setting of the Kamloops area, and the upper-air station situated outside of the modelling domain, CALMET was initially set to extrapolate surface winds vertically through the atmosphere. Similarity theory was used for the extrapolation, which uses a known profile to adjust both wind speed and direction with height. Although this selection is the default choice in CALMET when the upper-air station(s) is located outside of the modelling domain, a CALMET run using this option produced Level 5 (250m) wind speeds that were unrealistically high. The radiosonde data at Kelowna, as well as both mesoscale simulations, indicated a two-week average wind speed of approximately 3 m/s at this elevation, whereas the CALMET run using similarity theory produced an average wind speed of 8 m/s. In addition, the use of this CALMET option results in a portion of the upper-air radiosonde data being omitted from determination of upper level wind flow. Because of the likelihood that the Kelowna station is close enough to have upper level winds that reasonably approximate those over Kamloops, no surface wind extrapolation was ultimately used. CALMET determined the upper air wind by interpolating between the twice daily radiosonde data. This model selection produced upper air wind speeds that are much closer to both the observed and mesoscale model means.

Three other CALMET runs were conducted, each utilizing surface data with one station omitted. These are referred to as the '*N-1*' runs. Each was validated against wind data from the one station not used as input to the model. One of the three runs omitted the wind data from both the EC and the WLAP surface stations, due to their close proximity. The surface winds from this run were validated at the WLAP station location, since the WLAP anemometer has a lower threshold wind speed than the EC (airport) anemometer. The CALMET model settings for these runs were identical to those used in *BENCHMARK*.

3.2 CALMET MODELLING USING SURFACE OBSERVATIONS AND PROGNOSTIC UPPER-AIR DATA

Two CALMET runs were conducted using input data from all 5 surface stations and upper air fields from the RAMS and MC2 datasets. The two CALMET runs, referred to as *'OBS+RAMS'* and *'OBS+MC2'* used the same model settings as the CALMET runs using surface and upper air observations, with one exception. CALMET has two options for determining the 3D temperature field: 1) the use of prognostic fields alone, or 2) by using a combination of observed surface temperatures and prognostic temperatures above the surface. Since use of the prognostic fields alone produces identical temperature structure to the *no obs* runs, the latter choice was used. *OBS+RAMS* and *OBS+MC2* were not validated with surface wind data, because the surface winds for these two model runs are identical to those from *BENCHMARK*. The upper-air fields from the two CALMET runs were compared to the fields from the *BENCHMARK* run.

3.3 CALMET MODELLING USING PROGNOSTIC FIELDS IN 'NO OBS' MODE

Two CALMET *no obs* runs were conducted for each prognostic dataset. CALMET has the option of using the mesoscale winds directly (as a Step 1 Wind Field) or as an initial wind field that is adjusted by the internal Diagnostic Wind Module (DWM). The CALMET runs using the mesoscale winds directly are referred to as *'RAMS'* and *'MC2'* whereas the CALMET runs using the DWM are called *'RAMS+DWM'* and *'MC2+DWM'*. The same CALMET options used in *BENCHMARK* were chosen for these runs, with the exception that cloud cover data had to be derived from the prognostic fields instead of from station observations.

In *no obs* mode, CALMET requires cloud cover fractions that either have to be specified in an external data file, or calculated from relative humidity values at 850 mb. Since no guidance was available in the CALMET manual on the necessary format of the external data file, the second option was chosen and cloud cover fractions were internally calculated from the simulated humidity parameters at 850 mb. With this option, all CALMET ceiling heights are set at 8000 ft.

3.4 CALMET MODELLING USING PSEUDO-STATIONS DERIVED FROM PROGNOSTIC FIELDS

Data was extracted from both the RAMS and MC2 datasets to construct 10 'pseudo' surface stations and 1 pseudo upper-air station in the Kamloops domain. The locations of the pseudo stations were identical for each dataset and were chosen to adequately represent the varied topography in the modelling domain. The pseudo-station locations are shown in Figure 3.2. The location of the upper-air pseudo station was set at a higher elevation outside the valley. In contrast to actual radiosonde data, the upper-air pseudo-station was constructed with hourly values for each parameter. These CALMET runs are referred to as '*RAMS_PSEUDO*' and '*MC2_PSEUDO*'.

When using surface and upper-air station data, CALMET requires both cloud cover and ceiling height information from at least one surface station (for *BENCHMARK*, this data is provided in the EC YKA surface station dataset). Although the cloud cover information was available from the RAMS fields, the MC2 fields did not include this data. As an alternative, the RAMS cloud cover values were used to represent both the *RAMS-PSEUDO* and the *MC2-PSEUDO* CALMET runs. Ceiling height was not available from either of the prognostic fields. Based on the high frequency of 'unlimited' ceiling heights indicated in the YKA surface station data, all RAMS and MC2 surface pseudo-stations were constructed with unlimited ceiling heights for each hour. Setting the ceiling heights in this manner is similar in effect to the CALMET subroutine used for *'no obs'* runs when cloud data is not available (ceiling set to 8000 ft).

A summary of all CALMET meteorological configurations is provided in Table 3.3.

Figure 3.2: Location of Pseudo-Stations

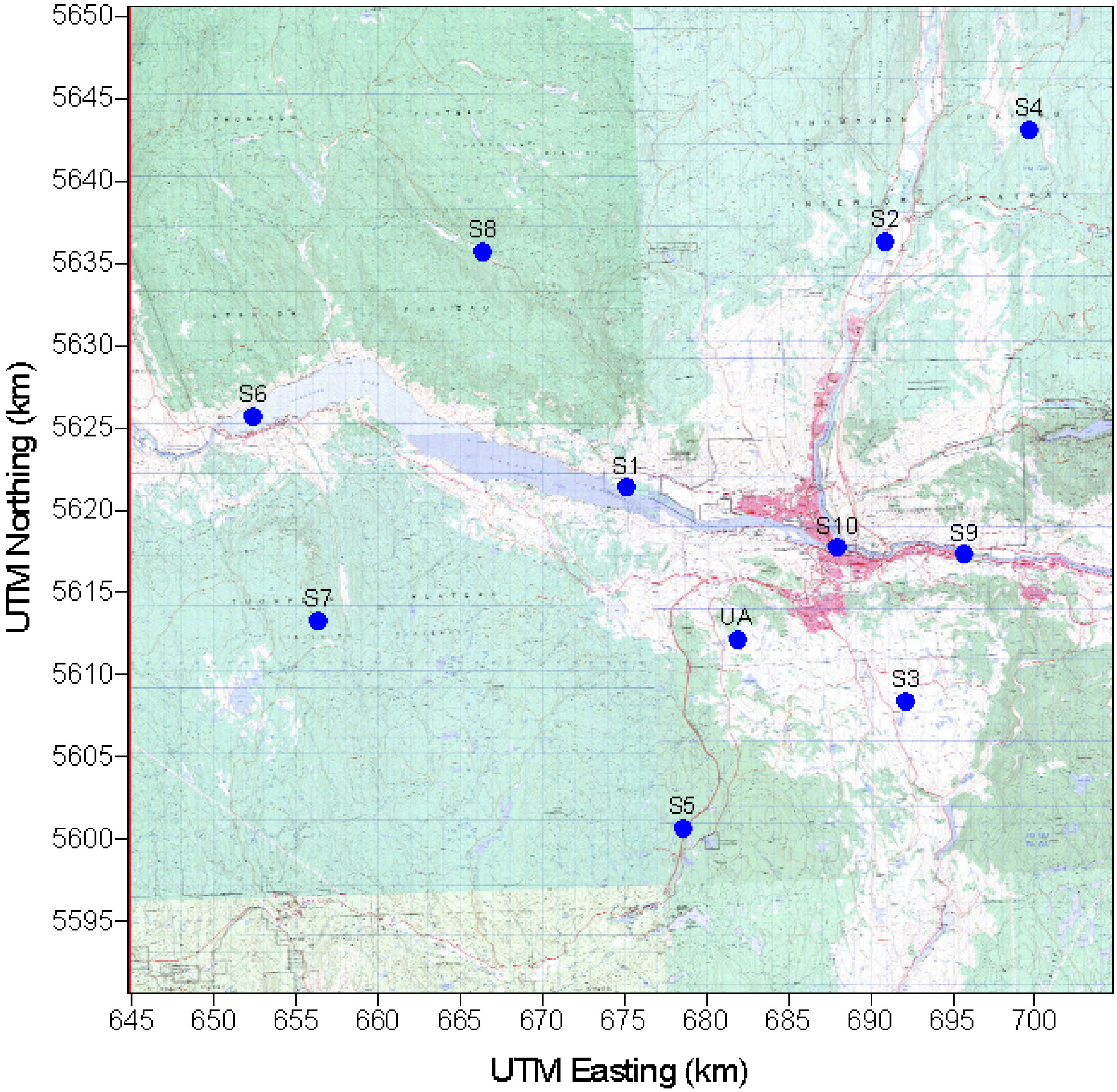

Table 3.3: Summary of CALMET Modelling Scenarios

Meteorological Simulation	Explanation of Modelling Methodology
BENCHMARK	CALMET run using 5 observed surface meteorological stations in the domain and 1 upper air station from Kelowna.
OBS (N-1)	CALMET runs using winds from 4 observed surface meteorological stations (and 3 for the case of the WLAP validation) and 1 upper air station from Kelowna. By omitting one station, model validation is possible at that one location.
OBS+PROG	CALMET runs using all 5 surface meteorological stations and prognostic fields for upper-air data. Runs include '*OBS+RAMS*' and '*OBS+MC2*'.
PROG	CALMET runs in 'no obs' mode using prognostic fields. Runs include *'RAMS'* and *'MC2'*.
PROG+DWM	CALMET run in 'no obs' mode using prognostic fields as initial guess and the DWM to adjust the resulting wind fields. Runs include *'RAMS+DWM'* and *'MC2+DWM'*.
PSEUDO	CALMET run using surface and upper air 'pseudo-stations' constructed from prognostic fields. Runs include *'RAMS_PSEUDO'* and *'MC2_PSEUDO'*.

4.0 Discussion of Results

4.1 MODEL INTERCOMPARISON AND VALIDITY

There has been some indication that the performance of CALMET improves when using mesoscale fields in combination with meteorological observations. For example, one recent study found that a CALMET simulation improved when using MM5 fields in addition to meteorological observations versus the use of observations alone[5]. In this case, judgment was based on both surface wind validation and upper level wind comparison against data from a wind profiler. However, the use of numerical data without the support of surface observations may introduce problematic features within the boundary layer.

Hanna and Yang suggest an evaluation methodology to assess the mesoscale model parameters that are commonly used as inputs to transport and dispersion models[6]. This framework is applied to the prognostic fields directly (i.e., before ingestion to a model such as CALMET). However, much of it is equally suitable for assessment of CALMET fields. Hanna and Yang applied the evaluation to four different mesoscale model simulations, the summary of which provides indication of the 'typical' errors that are associated with higher resolution mesoscale fields. Many of the evaluation procedures used in this study follow those used by Hanna and Yang, with some modifications and additions.

4.2 SURFACE WIND VALIDATION

Common validation for a mesoscale model simulation includes surface wind statistics such as Root Mean Square Error (RMSE) for vector winds, wind speed and wind direction. Modelling winds for the period of this study is particularly challenging, due to generally calm conditions and complex topography. The standard deviation of observed wind direction is known to increase at low wind speeds. During stagnant conditions, the ability of a typical anemometer to correctly capture the hourly mean wind speed, and particularly direction, is suspect. To account for this, a possible validation strategy is to use wind data only for those hours having speeds in excess of 2 or 3 m/s. However, a high percentage of the observed and modelled winds in this study are below this threshold, so the methodology cannot be adopted. Because of this, model error in wind direction may be higher than that determined in other model validation studies.

Surface wind validation was completed for three of the five surface observation stations that were available for the two-week period. The RAMS and MC2 CALMET runs did not use any of

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[5] Chandrasekar et al, 2003. *Evaluating the performance of a computationally efficient MM5/CALMET system for developing wind field inputs to air quality models*. Atmospheric Environment **37**, 3267-3276.

[6] Hanna, S.R., and R. Yang, 2001. *Evaluation of Mesoscale Models' Simulations of Near-Surface Winds, Temperature Gradients, and Mixing Depths*. Journal of Applied Meteorology, **40**, 1095-1104.

these five surface stations in their respective model runs. To obtain unbiased wind predictions from the CALMET model using observation stations, three different CALMET runs were conducted, with each simulation omitting the data from one surface station. There are two important choices that were made for this validation: 1) validation was not completed for the Kam2 station, since it is on the edge of the modelling domain, and 2) both the EC and WLAP station winds were omitted from the surface data fed to CALMET when validating CALMET winds at the WLAP station (due to the fact that the EC station is quite close to WLAP and in the same valley).

Surface winds from the prognostic-derived CALMET runs were also validated with the same surface meteorological station data. The Hanna and Yang study indicates the following ‘expected’ results for prognostic-derived fields:

- RMSE for wind speed will be approximately 2 – 3 m/s for a ‘wide range’ of wind speeds;
- RMSE for wind direction will be approximately 50 - 60^{o} for winds of ‘about 3 – 4 m/s’.

4.2.1 Outcome

Tables 4.1 to 4.3 present the results of the surface wind validation for each modelling methodology, with the exception of the *OBS+PROG* runs that used the data from all surface stations as input. The RMSE scores show that each model has relatively high error at times. The error in wind speed is similar for each CALMET run and in the ‘expected’ range. In contrast, RMSE for wind direction is generally higher. This may be due to the lower observed wind speed averages (and thus greater observed wind direction variability) than those experienced in the Hanna and Yang work. The RMSE scores do not distinguish any one CALMET run better or worse than the others at predicting surface winds. It is worth noting, however, that the CALMET run using observations alone achieves similar statistical validation results to the runs using numerical (mesoscale model) data.

The period mean wind speed and direction values may be a better indicator of model skill for calm periods such as the one in this study. Scalar mean wind direction and mean wind speed are shown, as were used in the Hanna and Yang work. The observed mean wind speeds realized at the KAM1 and especially the WALLOPER stations are actually higher (by a small amount) than the values shown, due to some low wind speeds being recorded as zero. At no time do the numerical models simulate zero wind speeds.

Table 4.1: Surface Wind Comparison for WALLOPER station

	Mean For Two-Week Period		Root Mean Square Error (n = 328)			Frequency of modelled wind direction within 45° of observed
	Speed (m/s)	Wind Direction (°)	Vector (m/s)	Speed (m/s)	Direction (°)	
OBSERVED DATA	**2.0**	**245**	-	-	-	-
OBS (N-1)	1.2	185	2.5	2.0	74	29%
RAMS	2.3	260	2.9	1.7	77	24%
RAMS+DWM	3.0	207	3.5	2.0	72	17%
RAMS_PSEUDO	2.2	217	2.5	1.6	55	42%
MC2	1.8	269	2.4	1.7	50	54%
MC2+DWM	1.9	271	2.9	1.9	60	37%
MC2_PSEUDO	1.3	272	2.2	1.6	53	49%

Table 4.2: Surface Wind Comparison for WLAP station

	Mean For Two-Week Period		Root Mean Square Error (n=328)			Frequency of modelled wind direction within 45° of observed
	Speed (m/s)	Wind Direction (°)	Vector (m/s)	Speed (m/s)	Direction (°)	
OBSERVED DATA	**2.2**	**152**	-	**-**	**-**	**-**
OBS (N-1)	1.3	192	2.4	1.5	88	30%
RAMS	1.7	149	2.4	1.2	75	49%
RAMS+DWM	1.8	152	2.4	1.2	76	50%
RAMS_PSEUDO	1.2	188	2.4	1.2	87	20%
MC2	0.9	162	2.6	1.6	98	14%
MC2+DWM	0.7	155	2.5	1.7	96	23%
MC2_PSEUDO	0.2	191	2.2	2.0	83	21%

Table 4.3: Surface Wind Comparison for Kam1 Station

	Mean For Two-Week Period		Root Mean Square Error (n=328)			Frequency of modelled wind direction within 45° of observed
	Speed (m/s)	Wind Direction (°)	Vector (m/s)	Speed (m/s)	Direction (°)	
OBSERVED DATA	**1.4**	**187**	-	-	-	-
OBS (N-1)	2.0	163	2.1	1.3	86	30%
RAMS	2.3	187	2.4	1.6	78	34%
RAMS+DWM	2.9	181	3.0	2.0	83	34%
RAMS_PSEUDO	1.3	204	1.8	1.0	84	33%
MC2	0.9	220	1.5	0.9	75	39%
MC2+DWM	1.1	211	1.6	0.9	83	34%
MC2_PSEUDO	0.3	221	1.4	1.1	83	30%

The following observations are based on differences between modelled and observed mean wind speed and direction:

- Mean values for the CALMET N-1 runs are not a good representation of observations at 2 of the 3 station locations.
- RAMS *no obs* runs provided mean wind values reasonably close to observations at 2 station locations and very close to observations at the WLAP station (in the valley).
- MC2 *no obs* runs provided mean wind values reasonably close to observations at 2 station locations, but significantly under-predicted mean wind speed at the WLAP station (in the valley).
- The use of the diagnostic wind module (DWM) with the CALMET *no obs* runs did not significantly change model wind directions, except in one case (WALLOPER station for RAMS+DWM). The use of the wind module tended to increase wind speeds at the station locations, although usually by just a small amount.
- The use of prognostic pseudo-stations did not lead to improvements over CALMET runs fully utilizing mesocale fields (*no obs* runs).

Tables 4.1 to 4.3 also indicate the frequency that each CALMET run ‘correctly predicted’ wind direction at the station locations. For the purposes of this study, a model prediction within 45° of the observed wind direction was considered reasonably accurate. At each station location, the percentage of time the model run had wind direction within 45° of the observed value was determined. For the CALMET N-1 runs, this occurred approximately 30% of the time for each station. The *no obs* runs each achieved higher frequencies at two station locations, but lower at one station.

Wind rose (WR) diagrams for model and observed surface winds were constructed to visualize how well each model predicted the overall pattern of wind speed and direction experienced at the 3 station locations. The WR diagrams are shown in Appendix A. The following observations are based on features of the WR diagrams:

- There is great variability in the predicted surface wind pattern between the CALMET runs.
- The CALMET *N-1* runs do not reproduce the observed surface wind circulation better than the prognostic-derived runs, except presumably near those surface station locations used as input to the model.
- There is little difference in predicted surface wind circulation between *no obs* runs when using the CALMET terrain adjustment (DWM) and when not.
- There are large differences in predicted winds between *no obs* runs and corresponding pseudo-station runs (i.e., *RAMS* vs. *RAMS_PSEUDO*). In general, the pseudo-station runs are poorer at predicting surface wind patterns compared to the *no obs* runs.
- The MC2 *no obs* WR diagrams match observed diagrams reasonably well out of the valley (WALLOPER and KAM1), but not well in the valley (WLAP).
- The RAMS *no obs* WR diagrams are a good match to observations in the valley (WLAP), but not as good as MC2 outside of the valley (WALLOPER and KAM1).
- The only close match between simulated and observed surface winds occurs with the RAMS *no obs* runs at the WLAP station

4.3 TEMPERATURE AND STABILITY ASSESSMENT

CALMET BENCHMARK temperatures were compared against predicted temperatures from all prognostic-derived CALMET runs, both in the form of average surface temperatures and average vertical temperature gradients through Layer1 to Layer 4 (surface to 150m height). In addition, CALMET mixing heights and Pasquill-Gifford stability classes were compared, due to the strong influence these parameters can have in the CALPUFF dispersion model. The temperature and stability comparison was conducted at the WLAP station location, since there is greater interest (and difficulty) simulating boundary layer structure in valley locations.

Although a rigorous discussion of the CALPUFF model itself is beyond the scope of this study, some general discussion of the model routines is necessary to understand what influence boundary layer temperature and stability parameters may have on dispersion modelling. Unless direct measurements of turbulence are available (which is almost never the case), CALPUFF determines horizontal and vertical Gaussian dispersion coefficients from CALMET meteorological parameters using one of two different methods: 1) analysis of micrometeorological variables (such as u_*, L, h and w_*), or 2) determination of Pasquill-Gifford

(PG) stability classes[7]. The former method is typically the one chosen for CALPUFF dispersion modelling in B.C., and is the recommended (default) choice in the CALMET manual. In this study, the choice of comparing mixing heights and PG classes was made due to both the potential importance of these parameters in the CALPUFF dispersion model (depending on selection of model options), and the common use of these parameters in other dispersion models.

Evening mixing heights in the CALMET model are largely dependent on surface temperatures and cloud cover. Daytime mixing heights are proportional to both the surface heat flux (which in turn depends on cloud cover, surface temperature and wind speed) and the vertical temperature profile in the layer above the previous hours' mixing height[8]. The more simplistic PG classes derive from cloud cover, surface wind speed and time of day[9]. Due to the significant effect cloud cover has in the determination of the two CALMET parameters, a simple comparison of EC YKA observed cloud cover amounts to RAMS cloud cover fractions at the nearest pseudo station location was completed and is shown in Table 4.4. At this one location, RAMS did not predict full cloud cover at any time, although observations at YKA show this occurred 33% of the time. A check of the other RAMS pseudo-station locations shows that full cloud cover is predicted at other locations, although very infrequently. MC2 cloud cover fractions were not in the output fields constructed for this study.

Table 4.4 Observed Versus RAMS Cloud Cover Fractions

Cloud Fraction (tenths)	RAMS_PSEUDO (nearest station) (%)	EC YKA (%)
0	52	10
1	14	4
2	18	12
3	6	8
4	7	7
5	2	8
6	0	4
7	0	7
8	0	6
9	0	12
10	0	33

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[7] A User's Guide for the CALPUFF Dispersion Model. http://www.src.com/calpuff/calpuff1.htm

[8] A User's Guide for the CALMET Meteorological Model. http://www.src.com/calpuff/calpuff1.htm.

[9] Turner, D.B., 1994. *Workbook of Atmospheric Dispersion Estimates, 2nd Edition*. Lewis Publishers.

One possible cause for the differences shown in Table 4.4 may be the frequent development of low level cloud within the valley settings of the Thomson Okanagan. During the winter months, it is quite common for the valley-based communities of Kamloops, Vernon and Kelowna to experience prolonged periods of complete sky cover, while conditions at higher elevations are generally clear. The RAMS model, at 1 km grid cell spacing, may not be able to develop this localized feature and instead simulate cloud conditions more representative of the region as a whole. It is not known whether the MC2 simulation contained the same characteristic.

The Hanna and Yang study indicates the following typical deficiencies in mesoscale temperature-related parameters near the surface:

- vertical temperature gradients in the lowest 100m during the night are generally underestimated, implying predicted boundary layer stability that is not as great as observed; and
- modelled mixing heights are within 20% of observed values 60% of the time, but the margin of error in predicting low mixing heights (~300m) can be as much as a factor of 2–4.

4.3.1 Outcome

A comparison of modelled boundary layer temperatures is presented in Table 4.5. In addition, a graphical analysis of modelled mixing heights and PG classes is shown in Figures 4.2 and 4.3. As previously mentioned, the *OBS+PROG* runs used the option to utilize both observed surface temperatures and prognostic upper air temperatures in the construction of 3D temperature fields. For these CALMET runs, the choice of using prognostic data alone for determination of 3D temperature fields would result in exactly the same temperature structure as produced in the *no obs* runs.

Table 4.5: Temperature Comparison

CALMET SIMULATION	MORNING (4 A.M.)			AFTERNOON (4 P.M.)		
	Mean Surface Temperature (n=14)	Mean Vertical Temperature Gradient Near Surface (°C/100m)	Max Vertical Temperature Gradient Near Surface (°C/100m)	Mean Surface Temperature (n=14)	Mean Vertical Temperature Gradient Near Surface (°C/100m)	Minimum Vertical Temperature Gradient Near Surface (°C/100m)
BENCHMARK	**272.0**	**+1.1**	**+2.5**	**276.6**	**-0.8**	**-1.1**
RAMS	273.1	-0.4	0.0	279.5	-0.4	-0.8
RAMS+DWM	273.1	-0.4	0.0	279.5	-0.6	-0.8
RAMS_PSEUDO	273.2	-1.8	+0.1	279.7	-0.6	-0.8
RAMS+OBS	272.0	+0.3	+3.1	276.6	+1.3	-0.5
MC2	265.9	+1.8	+2.8	267.0	+1.6	+0.3
MC2+DWM	265.9	+1.8	+2.8	267.0	+1.6	+0.3
MC2_PSEUDO	265.8	+1.7	+4.3	267.6	-0.8	-1.0
MC2+OBS	272.0	-2.7	+2.5	276.6	-2.9	-5.6

Each prognostic-derived CALMET run has surface temperature parameters significantly different than those in the BENCHMARK simulation. The following observations are made with respect to temperatures and temperature gradients near the surface:

- The RAMS-derived CALMET runs produced accurate morning surface temperatures, but over-predicted afternoon temperatures by approximately 3 degrees on average.
- The RAMS-derived CALMET runs did not simulate the range of vertical temperature gradients produced by the *BENCHMARK* simulation. In general, weaker gradients were predicted during the mornings and slightly stronger (less negative) were predicted during the afternoons.
- The MC2-derived CALMET runs did not accurately predict surface temperatures at this location. In addition, the diurnal range of temperatures is lower than that observed.
- The MC2-derived CALMET runs produced slightly stronger vertical temperature gradients during the mornings and much stronger gradients during the afternoons.
- The use of pseudo-stations yielded inconsistent results. Although surface temperatures are almost identical to those from the *no obs* runs, the general vertical temperature structure is significantly different: poorer in the case of RAMS and better for MC2.
- The use of surface observations with upper air mesoscale data produced surface temperatures identical to the *BENCHMARK*, but vertical temperature gradients were significantly different.

The results shown in Table 4.5 do not contradict the weaknesses discovered in the original prognostic fields as indicated in the earlier two WLAP studies. Instead, these outcomes provide a better articulation of the differences in the two prognostic datasets, in terms of significance to CALPUFF dispersion modelling. It is possible that the topography in the MC2 model was too coarse to resolve the valley locations accurately, leading to the modelled elevation of the WLAP surface station being higher than actual. This may explain the bias towards cooler predicted surface temperatures, but not the lower-than-observed diurnal variation. The authors of this study did not complete the MC2 simulations. The RAMS topographical dataset, and horizontal grid spacing was of finer resolution, and resolved the WLAP station elevation reasonably well (within approximately 15m). Mesoscale model surface temperatures depend strongly on elevation, and therefore simulated surface temperatures in complex terrain tend to be more accurate with greater horizontal grid resolution.

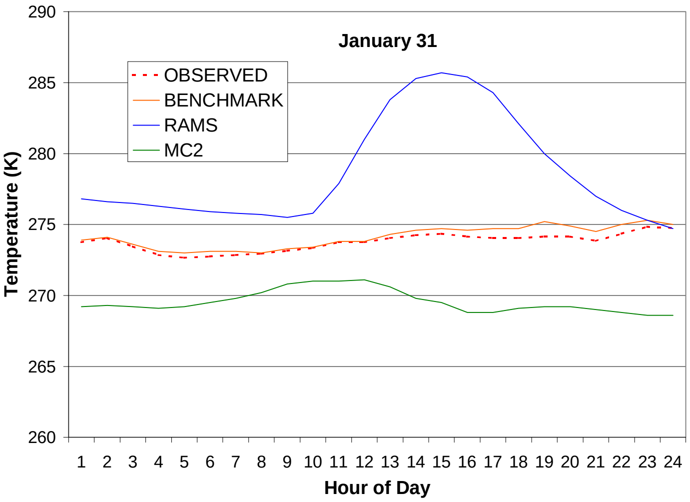
Table 4.5 also indicates that using a combination of observed surface temperatures and prognostic upper air temperatures in the development of 3D temperature fields can lead to improbable vertical temperature gradients near the surface. Use of this CALMET option at times produced temperature gradients significantly different than observed.

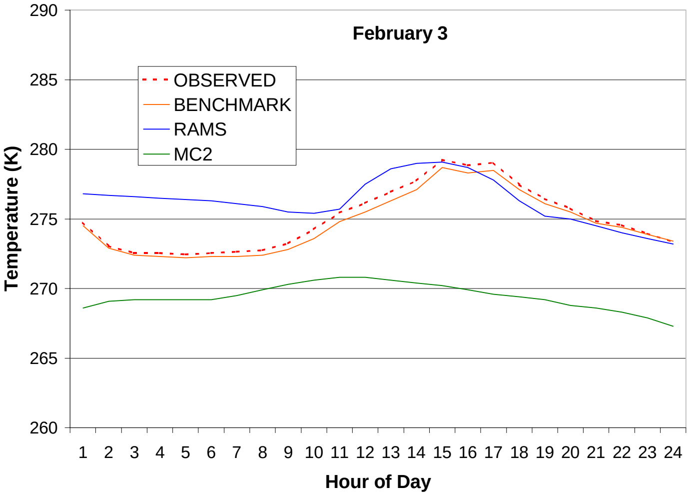
Hourly surface temperatures were extracted from the *BENCHMARK, RAMS and MC2* CALMET runs at the WLAP station location and compared to the observed diurnal pattern. The surface temperatures on January 31, February 3 and February 8 are shown in Figure 4.1. As expected, the *BENCHMARK* temperatures are virtually identical to the observed surface station temperatures. Overestimation of afternoon temperatures is evident for the *RAMS* run on January 31, although not on the other two days. The *MC2* temperatures show little variation for the three days, and peak earlier in the day than observed. In addition, cooler than observed temperatures are indicated at all times.

Figure 4.2 shows a comparison of *BENCHMARK* mean hourly mixing heights to prognostic-derived values. The *RAMS+DWM* and *MC2+DWM* parameters are not shown, as they are almost identical to the values determined in the *RAMS* and *MC2* CALMET runs. The *RAMS* mixing heights are both lower in the morning and higher in the afternoon than those in the *BENCHMARK* run. The cause is at least partly due to a combination of lower cloud fraction amount and higher afternoon surface temperatures. (It should be noted again that the cloud cover fractions for the *no obs* runs are not directly obtained from the mesoscale fields but are instead internally calculated in CALMET from the prognostic relative humidity field at 850 mb.) The RAMS-derived neutral-type temperature profiles near the surface during the evening and early morning hours evidently do not have a large impact on CALMET determination of mixing height. *RAMS_PSEUDO* heights show a similar trend to the *no obs* run, with evening mixing heights slightly lower.

The *MC2* run has mean hourly mixing heights lower than *BENCHMARK* at all hours of the day. Similar to the *RAMS* runs, lower cloud fractions may be partly responsible for the low evening heights, further decreased due to the cooler *MC2* surface temperatures. The low afternoon mixing heights are likely due to lower *MC2* surface temperatures and surface wind speeds, and stronger modelled vertical temperature gradients than those produced in the *BENCHMARK* run. Although the difference between *MC2* and *BENCHMARK* mixing heights are greater than for the *RAMS* values in the evening and early morning, the *MC2* values are closer on average in the afternoon. The mean afternoon mixing heights for *MC2_PSEUDO* are a very close match to those of *BENCHMARK*, although the reason for this is unclear.

Figure 4.1 Observed and Modelled Daily Surface Temperatures





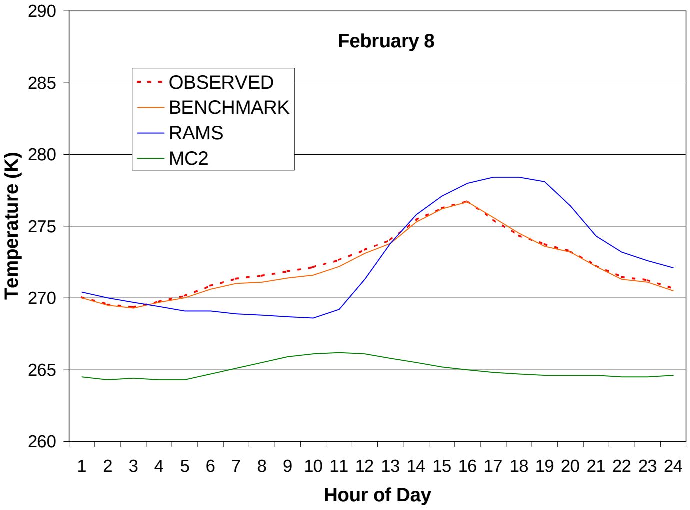
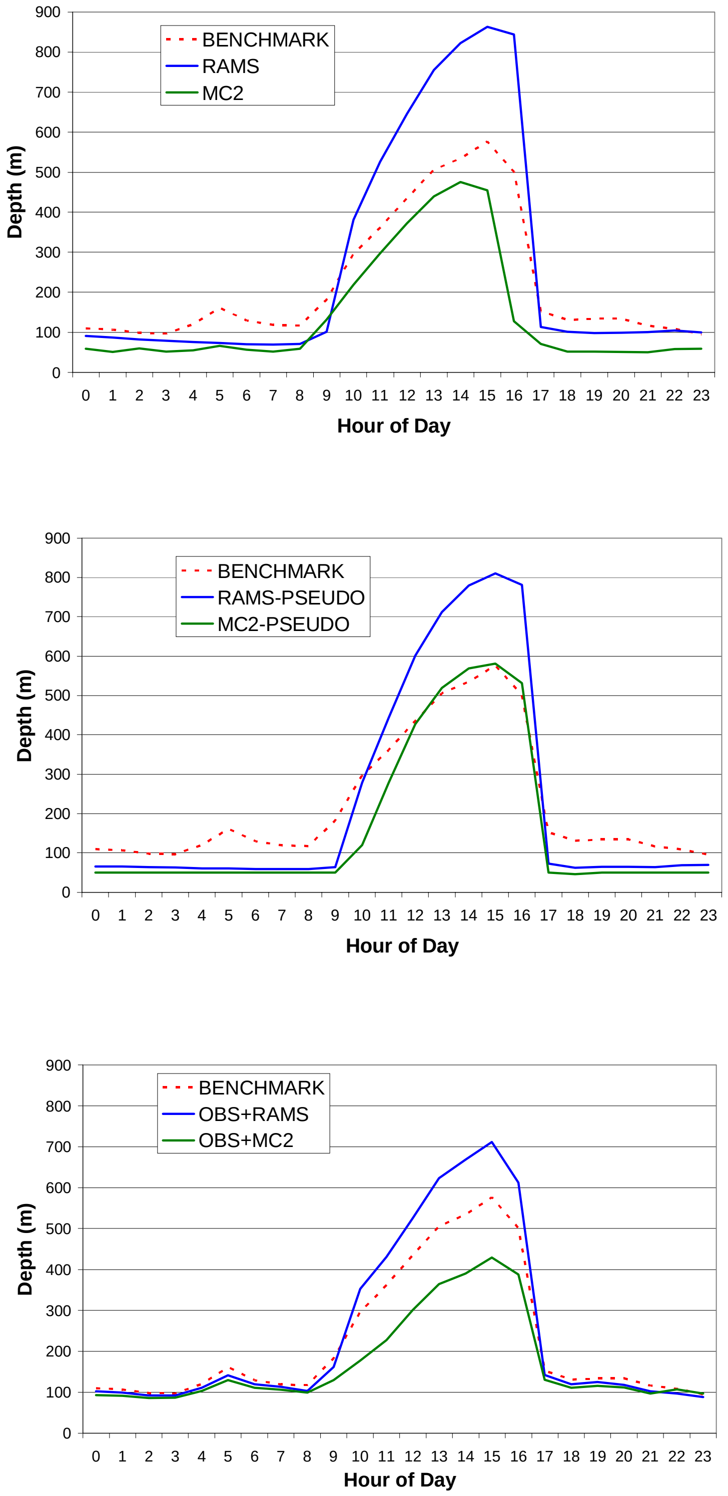


Figure 4.2: Mean Modelled Mixing Heights



The *OBS+RAMS* and *OBS+MC2* CALMET runs produce mean morning mixing heights that are almost a perfect match to those of *BENCHMARK*. This is not surprising, since in this case the same surface observations (surface temperature, cloud cover) are used in the prognostic-derived CALMET runs as in *BENCHMARK*. It is not readily apparent why the differences occur during the afternoons. The vertical temperature gradient above the previous hours' mixing height may be the cause – potentially weaker than observed in the case of *OBS+RAMS*, allowing increased growth of the Mixed Layer, and stronger than observed in the case of *OBS+MC2*. Hanna and Yang suggest that the temperature gradient above the Mixed Layer may have more significance to dispersion than the near-surface temperature profile in many situations[10].

Figure 4.3 shows the PG stability classes for each CALMET simulation, except for *RAMS+DWM* and *MC2+DWM*, which again produce stability parameters virtually identical to the *RAMS* and *MC2 no obs* runs. The Pasquill-Gifford Stability classes are defined in Table 4.6. The lower cloud fractions for each RAMS-derived CALMET run result in stability class 6 predicted twice as frequently as determined in the *BENCHMARK* run. In addition, class 5 and 4 are predicted less frequently. This is a similar situation to the PG classes developed in the MC2-derived CALMET runs, although stability class 4 is developed less frequently and class 2 more frequently than in the RAMS-derived runs.

The use of surface observations with prognostic upper-air data produces PG classes identical to those produced in *BENCHMARK*. This should be expected, since determination of this parameter is based solely on surface data.

Table 4.6: Pasquill-Gifford Stability Classes

PG Class	Description	CALMET PG Class
A	Strongly Unstable	6
B	Moderately Unstable	5
C	Slightly Unstable	4
D	Neutral Conditions	3
E	Slightly Stable	2
F	Moderately Stable	1

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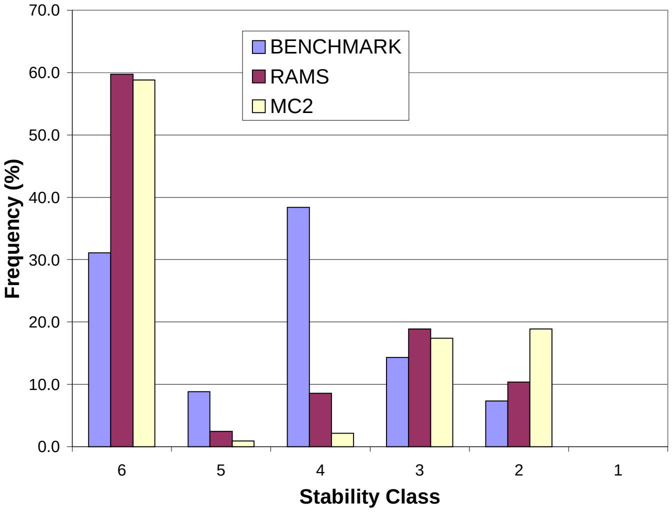
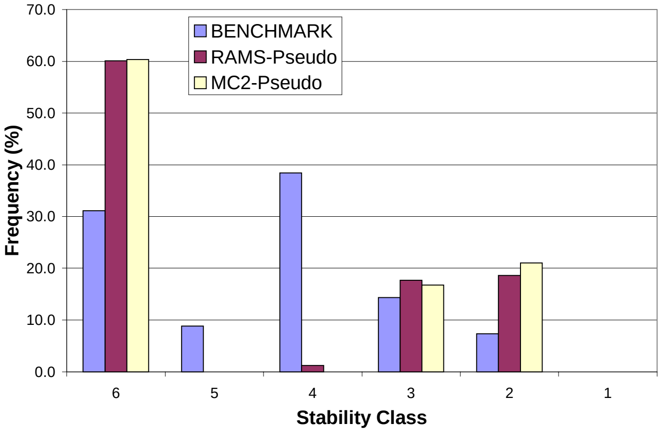
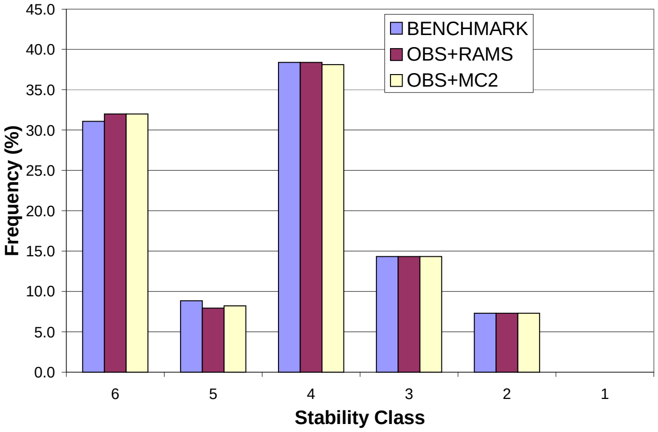
[10] Hanna, S.R., and R. Yang, 2001. *Evaluation of Mesoscale Models' Simulations of Near-Surface Winds, Temperature Gradients, and Mixing Depths*. Journal of Applied Meteorology, **40**, 1095-1104.

Figure 4.3: Modelled Pasquill-Gifford Stability Classes







4.3 UPPER LEVEL WIND ASSESSMENT

CALMET Level 5 winds were extracted to produce an upper level wind comparison for all simulations. The comparison is valid for winds in the layer 200-300m above ground over the WLAP meteorological station. With the *BENCHMARK* configuration, CALMET interpolates between radiosonde data points to represent the 22 hours that upper-air wind measurements are not available. All prognostic-derived CALMET runs used winds from the closest RAMS or MC2 layer; therefore, for these runs, the CALMET Layer 5 winds represent the hour-by-hour flow developed by the corresponding mesoscale models.

4.3.1 Outcome

A comparison of modelled wind in CALMET Level 5 is presented in Table 4.7. The CALMET prognostic-derived DWM runs are not shown, since they produced identical upper air winds to those runs not using DWM (i.e., *RAMS+DWM* vs. *RAMS*). Upper air (radiosonde) data from Kelowna is considered in addition to the wind parameters from the CALMET runs. The wind speed and direction values from the Kelowna station were determined at an elevation of 609m above sea level, which is the most representative elevation to CALMET Layer 5. The Kelowna winds are measured every 12 hours, and at this elevation may be somewhat influenced by the valley orientation below (which is roughly N-S). However, due to the synoptic high pressure system that persisted for the two week period, the Kelowna winds are likely a good approximation of the 250m wind flow over Kamloops.

Table 4.7: Upper Level (250m) Wind Comparison

	4 A.M. (n = 14)		**4 P.M. (n = 14)**		**Entire Period (n = 328)**	
	Mean Wind Speed (m/s)	**Scalar Mean Wind Direction (°)**	**Mean Wind Speed (m/s)**	**Scalar Mean Wind Direction (°)**	**Mean Wind Speed (m/s)**	**Scalar Mean Wind Direction (°)**
RADIOSONDE DATA (KELOWNA)	**2.8**	**212**	**2.8**	**184**	**2.8** **(n = 29)**	**198** **(n = 29)**
BENCHMARK	2.3	201	2.9	200	2.3	176
RAMS	2.9	235	2.9	217	2.8	223
RAMS_PSEUDO	5.2	278	6.0	257	5.5	267
OBS+RAMS	2.8	225	2.9	190	2.8	211
MC2	2.6	190	3.2	215	3.4	207
MC2_PSEUDO	5.0	244	4.5	239	4.9	241
OBS+MC2	2.4	208	2.8	215	3.1	205

The following observations are made from the comparison shown in Table 4.7:

- The *BENCHMARK* mean wind directions are very close to the observed Kelowna values, but the morning wind speeds are lower.
- The RAMS and MC2 *no obs* runs produce mean 250m wind speeds and directions that are very close to the observed Kelowna values. The wind speeds are higher than those in *BENCHMARK*.
- The PSEUDO runs for both mesoscale models do not produce 250m winds close to those at Kelowna or in the *BENCHMARK* run.
- The *OBS+RAMS* and *OBS+MC2* winds are nearly identical to those produced in the corresponding *no obs* runs, and are a good match to both *BENCHMARK* and the Kelowna upper-air data.

Table 4.7 indicates that simulated 250m winds are similar between the *RAMS* and *MC2* no obs runs. This should be expected, since both models use initialization and nudging fields derived from the same Eta model. As well, surface characteristics have much less influence at this height.

5.0 Discussion of Results

The comparisons made in this study indicate that each meteorological model (prognostic and deterministic) had difficulty reproducing observed station data. However, prognostic models such as RAMS and MC2 may better represent the large degree of variability in surface and near-surface winds. The results presented here only apply to calm conditions, and may not have bearing during periods with higher wind speeds, when the CALMET deterministic model (i.e., using station observations alone) has been shown to produce favourable wind predictions. When comparing modelled winds against independent station data in the Kamloops area, the CALMET model was found to simulate surface winds better when using prognostic fields as input compared to using data from 3 or 4 surface observation stations. Surface winds from the RAMS model, as processed through CALMET, were clearly a better representation of observed winds in Kamloops than were winds from the MC2 model. A likely cause for this difference is the coarser 2 km spacing of the inner MC2 grid (as compared to the 1 km RAMS grid), which would not adequately resolve the variation in topographical heights in and near the valleys. Outside of the valley, the MC2-derived CALMET runs performed much better in terms of surface wind predictions, reproducing the general circulation at two stations better than CALMET using observations and predicting wind direction better than the RAMS-derived CALMET runs.

In general, the preferred modelling approach to the exclusive use of high resolution prognostic data in the CALMET model was found to consist of using the prognostic fields without any adjustment from the internal Diagnostic Wind Module. In most cases, use of the DWM did not improve the surface wind fields, and did not significantly change any other modelled variables. The pseudo-station approach, in the configuration chosen, led to inconsistent results, and generally produced poorer surface wind fields.

Each prognostic model had difficulty simulating other boundary layer characteristics. In this respect, the two mesoscale models performed very differently. RAMS predicted surface temperatures in Kamloops reasonably well, but overestimated afternoon heating. MC2 consistently predicted cooler surface temperatures with little diurnal fluctuation. In addition, each model produced vertical temperature gradients that were significantly different than those determined from the Kelowna radiosonde data. Each model at times produced temperature gradients that were not a reasonable representation of near-surface conditions during a high pressure synoptic pattern. RAMS had a bias towards neutral stability overnight, whereas MC2 had a bias towards strong stability during the afternoons.

The difference in near-surface temperature gradients did not have a noticeable impact on CALMET determination of mixing heights and stability classes. With these parameters, simulated cloud cover had a dominating effect, in addition to hour-by-hour temperature changes at the surface. During the two week period, RAMS cloud cover amounts were not a good representation of observed cloud cover in the Kamloops area (MC2 cloud cover amounts could not be extracted from the fields acquired from UBC). RAMS predicted a high percentage of clear skies, with very few occasions of cloud amounts above 5 tenths. Over 30% of cloud observations at EC YKA were complete sky cover. The lower cloud amounts were primarily responsible for all prognostic-derived PG stability class distributions having far more occurrences of unstable conditions than were produced from the use of observations alone. The CALMET *no obs* runs did not actually use the prognostic cloud amounts directly, but instead internally calculated the values from relative humidity at 850 mb. This CALMET algorithm would not be able to capture low-level cloud if properly simulated in mesoscale model output. However, the fact that the prognostic pseudo-station runs (which used the RAMS cloud cover amounts directly) produced similar PG class distributions to the *no obs* runs indicates that the CALMET routine for calculating cloud cover was consistent with the actual RAMS cloud parameters. This may not have been the case with MC2 cloud cover.

CALMET uses a more sophisticated method for determining mixing heights than for the simplistic PG classes. Both RAMS- and MC2-derived CALMET runs produced lower mixing heights during the evening and early morning compared to those determined from observations alone. This is largely due to the lower predicted cloud cover amounts. The combined effect of low cloud cover and cooler-than-observed surface temperatures caused the MC2-derived mixing heights to commonly hover around the minimum CALMET limit of 50m during the evenings. During the afternoons, the RAMS-derived mixing heights at times were significantly higher than those based on observations. Greater surface heating during the day may be partly responsible, although differences between modelled and observed temperature profiles above the mixed layer may have also played a role. The MC2-derived values were much closer to, but lower than, the afternoon mixing heights determined from observations. In this case, low modelled wind speeds and little surface heating kept the Mixed Layer from growing as high as observations showed.

Both RAMS and MC2 simulated upper air winds near Kamloops that were a good representation of the upper air data from at Kelowna, and of that predicted from CALMET when using the Kelowna data as input. In this regard, the use of prognostic data can clearly be useful to a model such as CALMET, especially when an upper air station is not close the modelling domain in question.

The *'OBS+PROG'* modelling approach, blending surface observations with prognostic upper air data, produced identical surface-derived parameters (including PG stability classes) as CALMET modelling using observations alone. A benefit of this approach is potentially a better representation of upper air flow than would be achieved using observations alone. However, it was determined that afternoon mixing heights (which have a dependence on the prognostic vertical temperature gradient) can be considerably different when using one mesoscale model versus another. On average, *OBS+RAMS* produced a daily maximum mixed layer height of approximately 700m, whereas *OBS+MC2* produced a maximum of just over 400m. It is likely that the use of the two CALMET meteorological fields in CALPUFF would produce different results, depending somewhat on choice of CALPUFF modelling options.

The implications of this work are that the CALMET model may at times produce very different meteorological fields when using data from one prognostic model over another. Even the practice of combining surface data with upper air prognostic fields has the potential to produce different outcomes from the use of observation station data alone. However, these implications may be valid only for stagnant conditions similar to those experienced during the two-week period of this study. Such conditions are very challenging for both prognostic and deterministic models to represent.

The differences in boundary layer characteristics from the RAMS fields to the MC2 fields, and their likely impact on dispersion parameters, imply that in some cases a high resolution modelling simulation may not be appropriate to use for a detailed dispersion analysis, at least with a model such as CALPUFF. Previous CALMET studies have indicated that poorly characterized mesoscale fields cannot be adequately compensated for within the model, and may have a negative effect on dispersion results. Although this statement applies mainly to wind fields, the analysis of mesoscale data in this study shows that it may be equally applicable to temperature and stability related parameters. Mesoscale models currently have many available options for representation and parameterization of important physical processes; the choice of one scheme over another, or one grid resolution over another can sometimes be made for purposes of achieving computational stability and time efficiency. At this time, it is likely that a better representation of the atmospheric boundary layer can be achieved with a mesoscale model if it is configured with the specific intent of application towards dispersion modelling.

6.0 Conclusion

Two high resolution mesoscale simulations over the Thomson-Okanagan area of British Columbia were used to perform CALMET model runs over Kamloops using several different methodologies. The RAMS and MC2 model fields were used to construct both complete prognostic data input files ("MM5.DAT" type) and a number of pseudo-stations. CALMET runs were completed using prognostic input alone ("no obs" runs) and using a combination of surface station data and prognostic upper air fields. For both mesoscale models, the best approach to using the full prognostic fields in CALMET was determined to be the use of the fields without any internal adjustment from CALMET.

Analysis of the CALMET meteorological fields indicate that use of the full mesoscale fields produces superior 3D wind fields over use of 3 or 4 surface observation stations and 1 nearby upper air station during synoptic high pressure, low wind speed conditions. Each prognostic-derived CALMET run was able to reproduce surface station winds better than CALMET using observations in two out of three cases. The prognostic-derived CALMET runs did not achieve the same level of success in predicting other boundary layer parameters. Some of this difficulty, although less pronounced, was also noted in the CALMET runs using combined surface station/prognostic upper air input. Other than surface temperature, validation of other stability-related parameters was more difficult to achieve, as these values were not directly or indirectly measured. For these parameters, comparison of the prognostic-derived fields to those determined from a benchmark CALMET run, using all available surface and upper air data, was completed. The comparisons indicate that prognostic-derived meteorological fields can at times be significantly different than CALMET fields produced using observation data.

With respect to the use of the RAMS and MC2 mesoscale fields in CALPUFF dispersion modelling, the following strengths and weaknesses were noted:

RAMS (1 KM GRID SPACING)

- Good characterization of wind speeds at all station locations
- Good characterization of surface wind direction in the valley, and reasonable characterization of wind direction at higher elevations
- Good characterization of upper air wind speed and direction
- Good characterization of surface temperatures, although a small bias towards warmer afternoon temperatures
- Difficulty simulating surface based inversions; bias towards more neutral temperature profiles in the boundary layer
- Tendency to underestimate cloud cover in the valley
- Use of the fields in CALMET led to significantly different Pasquill-Gifford stability classes and mixing height distributions compared to the use of observation data

MC2 (2 km grid spacing)

- Tendency to underestimate wind speed
- Good characterization of surface wind direction at higher elevations
- Poor characterization of wind direction in the valley
- Good characterization of upper air wind speed and direction
- Consistently modelled cooler surface temperatures, with smaller diurnal variation than observed
- Bias towards strong positive vertical temperature gradients in the boundary layer, notably during the afternoons
- Use of the fields in CALMET led to significantly different Pasquill-Gifford stability classes and mixing height distributions compared to the use of observation data

7.0 Recommendations

The results of the analysis performed here give an indication of the potential differences in CALMET meteorological fields when using prognostic/mesoscale fields to either support, or replace the use of station data. For the purposes of *no obs* dispersion modelling (modelling using prognostic inputs only), some of the weaknesses determined in the modelled fields of this study can potentially serve as guidance towards assessment criteria of other mesoscale simulations.

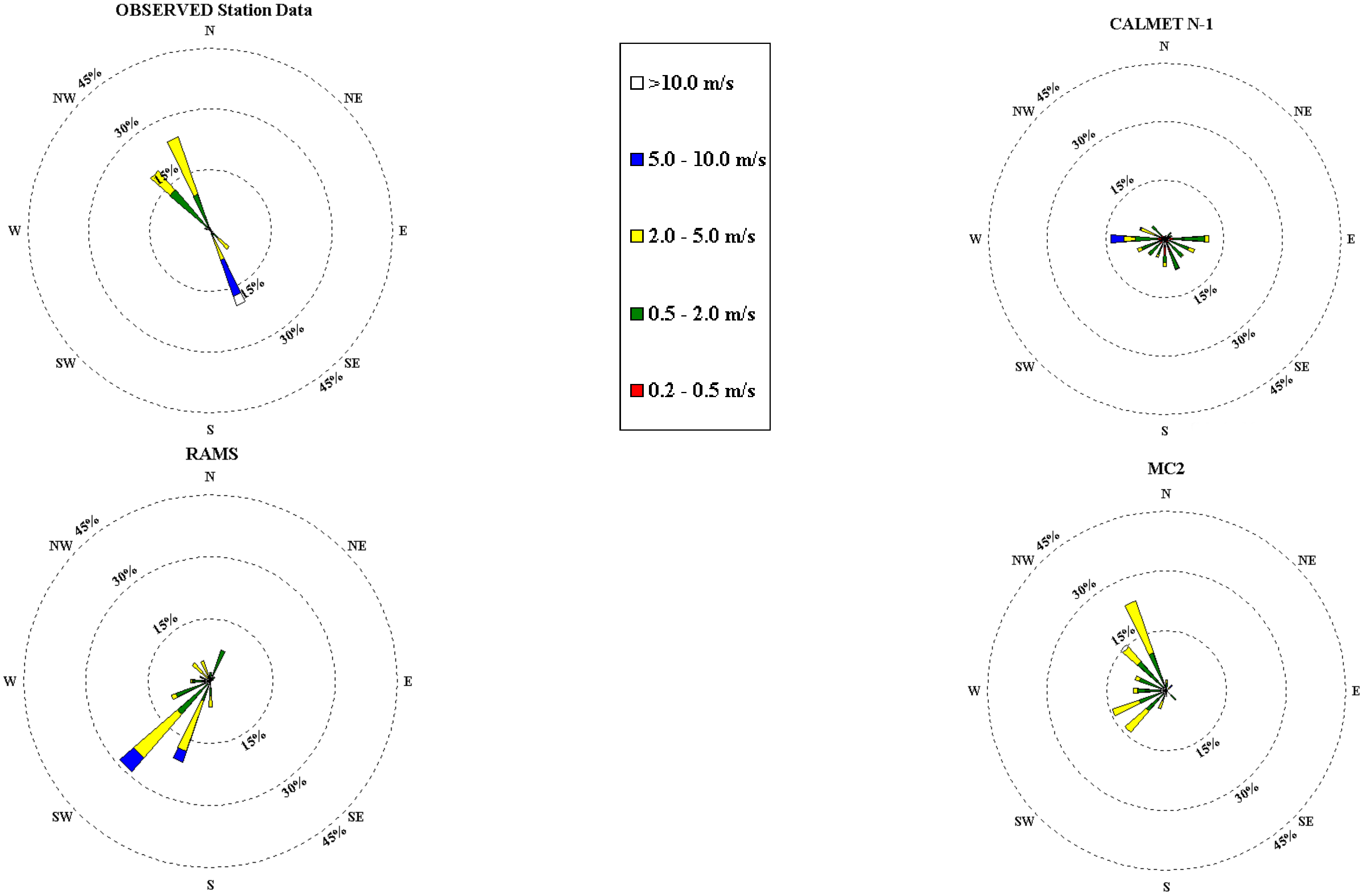
The conclusions reached in this report are based on the meteorological simulations of two mesoscale models over a relatively brief period of time. In addition, the fields are also somewhat dependent on the choice of surface, soil and cloud schemes within the models themselves. Similar studies concerning both assessment of other prognostic model simulations, and other synoptic conditions are needed.

Although weaknesses and/or differences were determined in the meteorological parameters derived from both mesoscale models, the actual effect of these characteristics on concentration predictions from a dispersion model such as CALPUFF has yet to be determined. Experience with the use of prognostic-derived CALMET fields in either actual or idealized CALPUFF dispersion modelling is needed to determine if differences between these fields and those constructed in the usual deterministic manner (using station data) warrants concern.

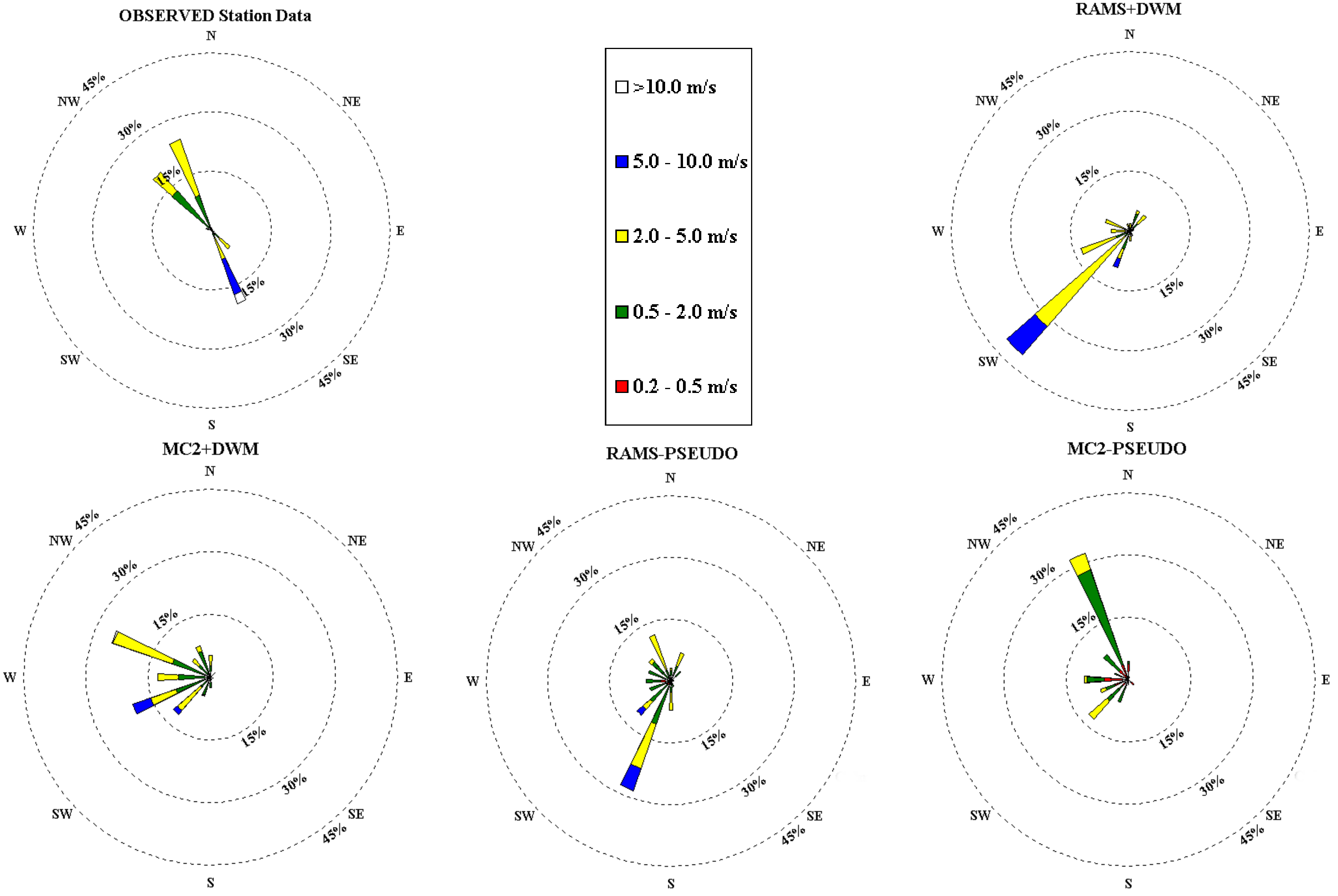
At present, a considerable amount of meteorological validation should be performed before a prognostic/mesoscale simulation is used to conduct *no obs* dispersion modelling. The validation should include qualitative comparisons such as the ones presented in this report.

APPENDIX A: WINDROSE DIAGRAMS

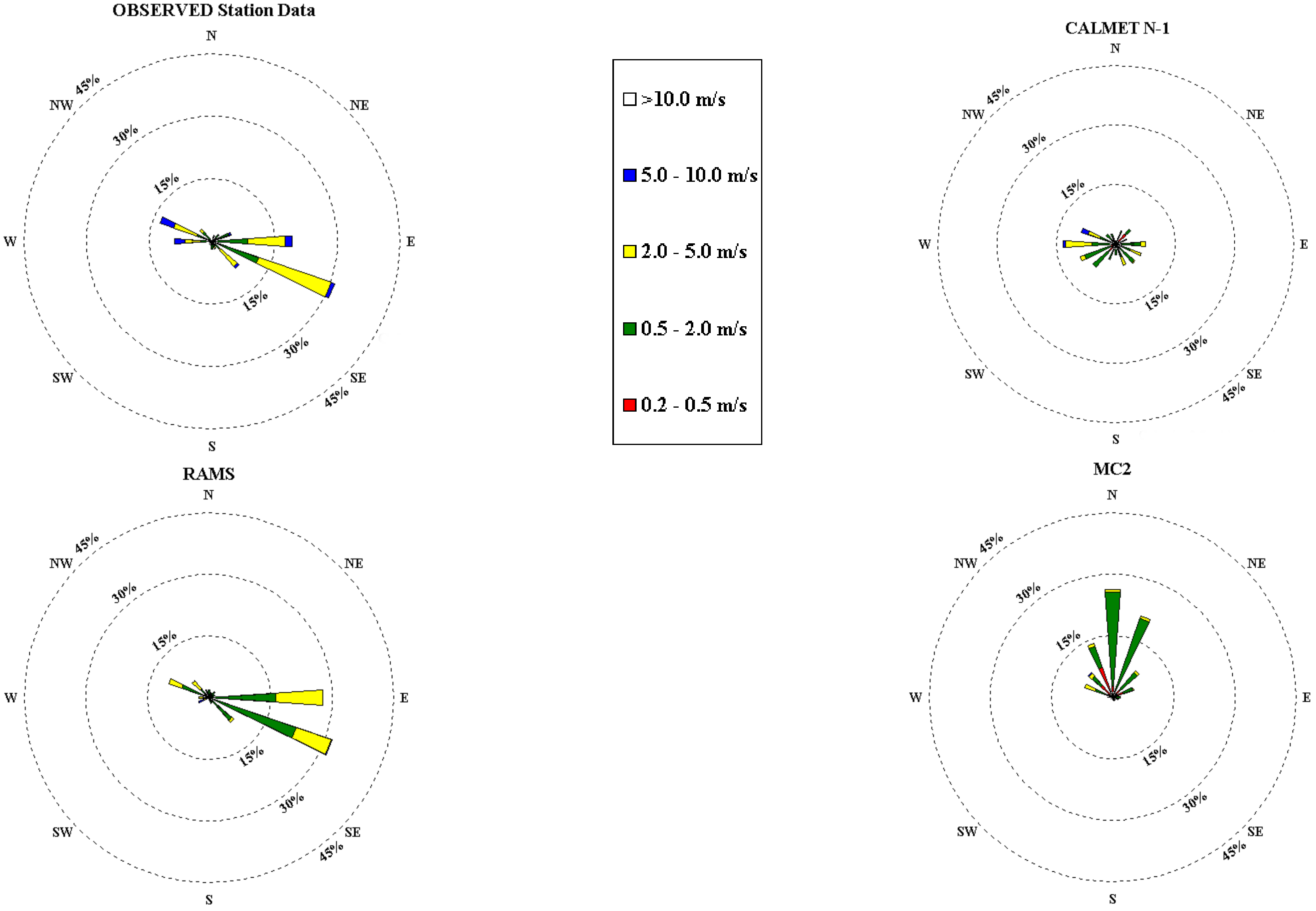
MoTH (WALLOPER) Station



MoTH (WALLOPER) Station (Continued)



B.C. MWLAP (WLAP) Station


OBSERVED Station Data

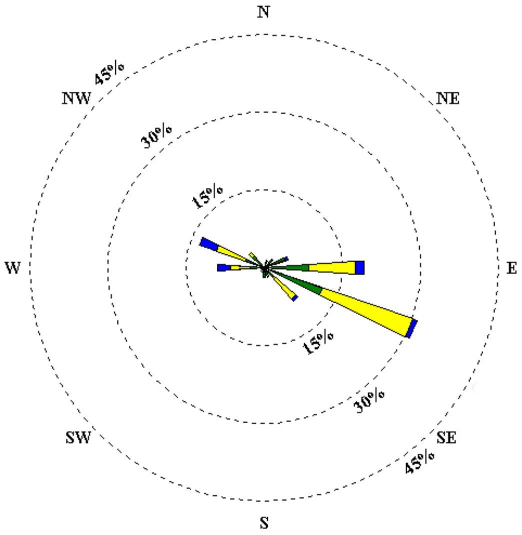
CALMET N-1

RAMS

MC2

B.C. MWLAP (WLAP) Station (continued)

OBSERVED Station Data



□ >10.0 m/s

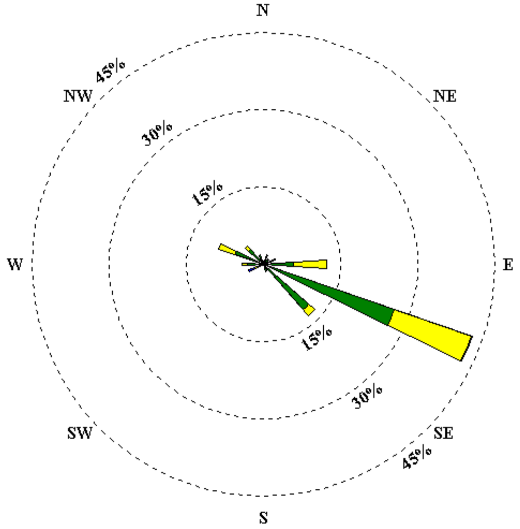
🟦 5.0 - 10.0 m/s

🟨 2.0 - 5.0 m/s

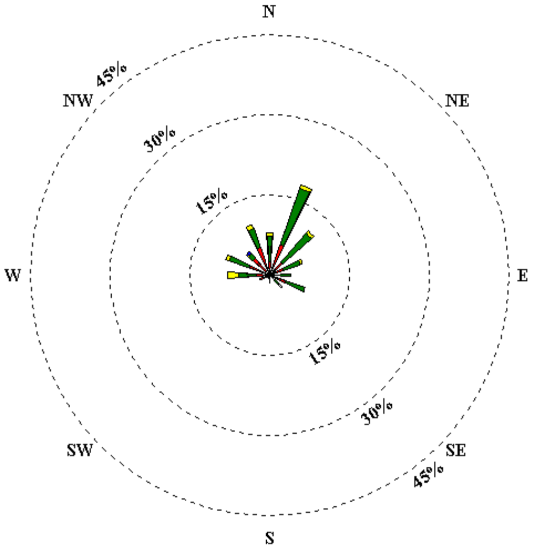
🟩 0.5 - 2.0 m/s

🟥 0.2 - 0.5 m/s

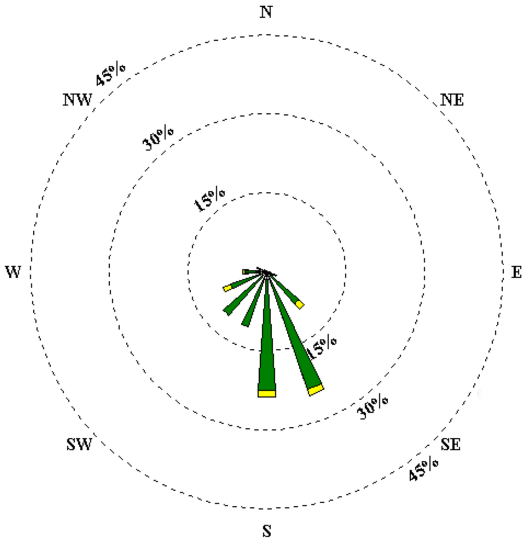
RAMS+DWM



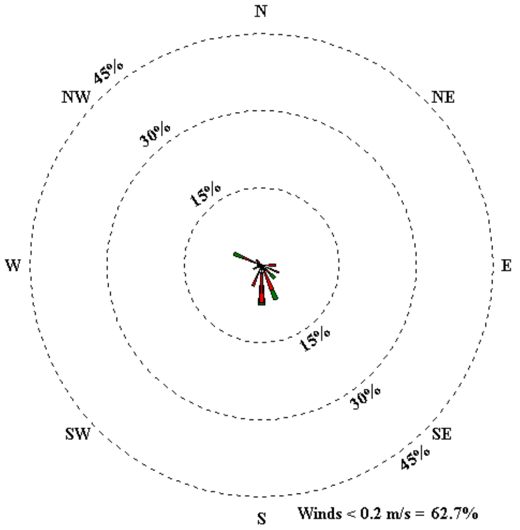
MC2+DWM



RAMS-PSEUDO

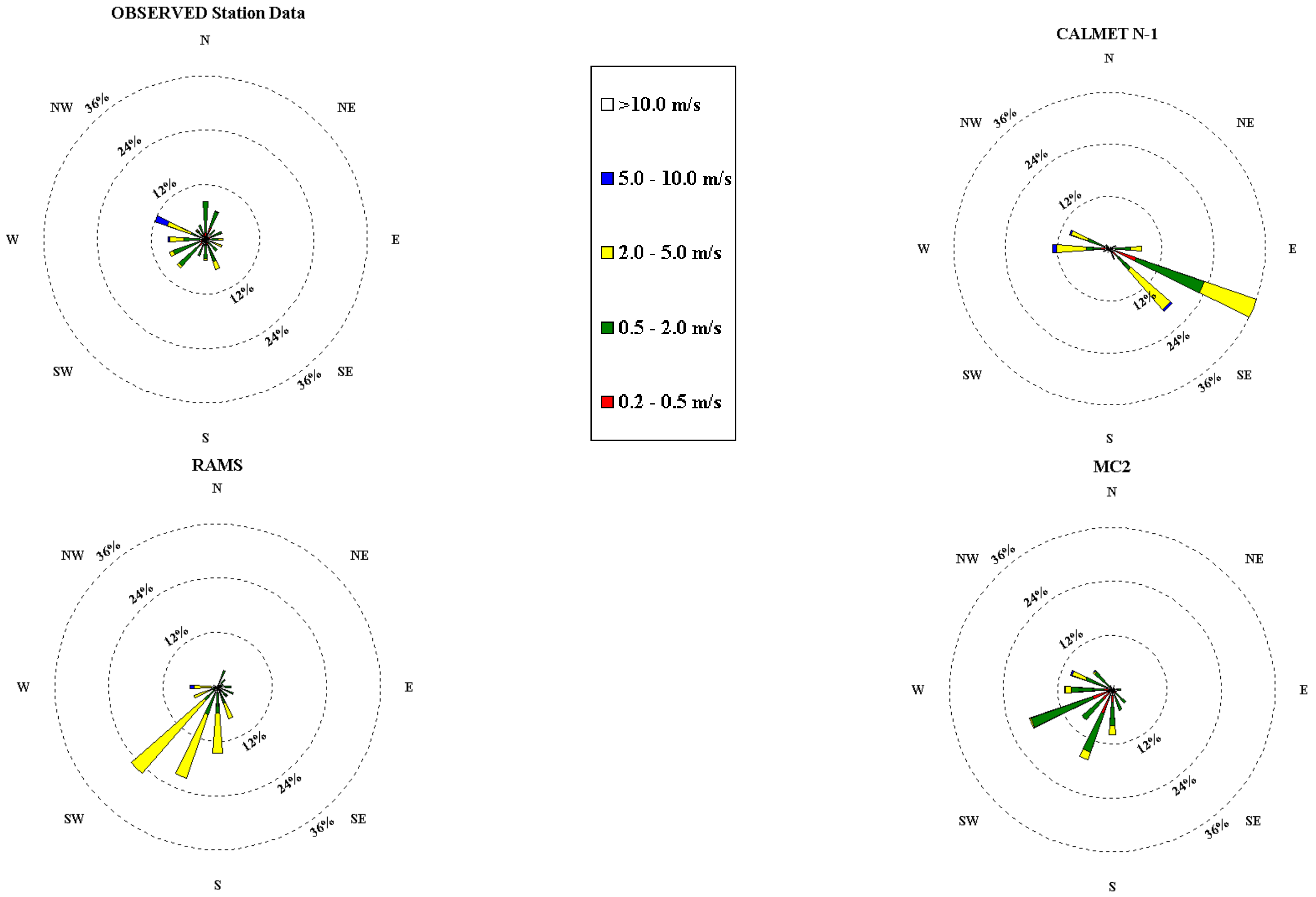


MC2_PSEUDO

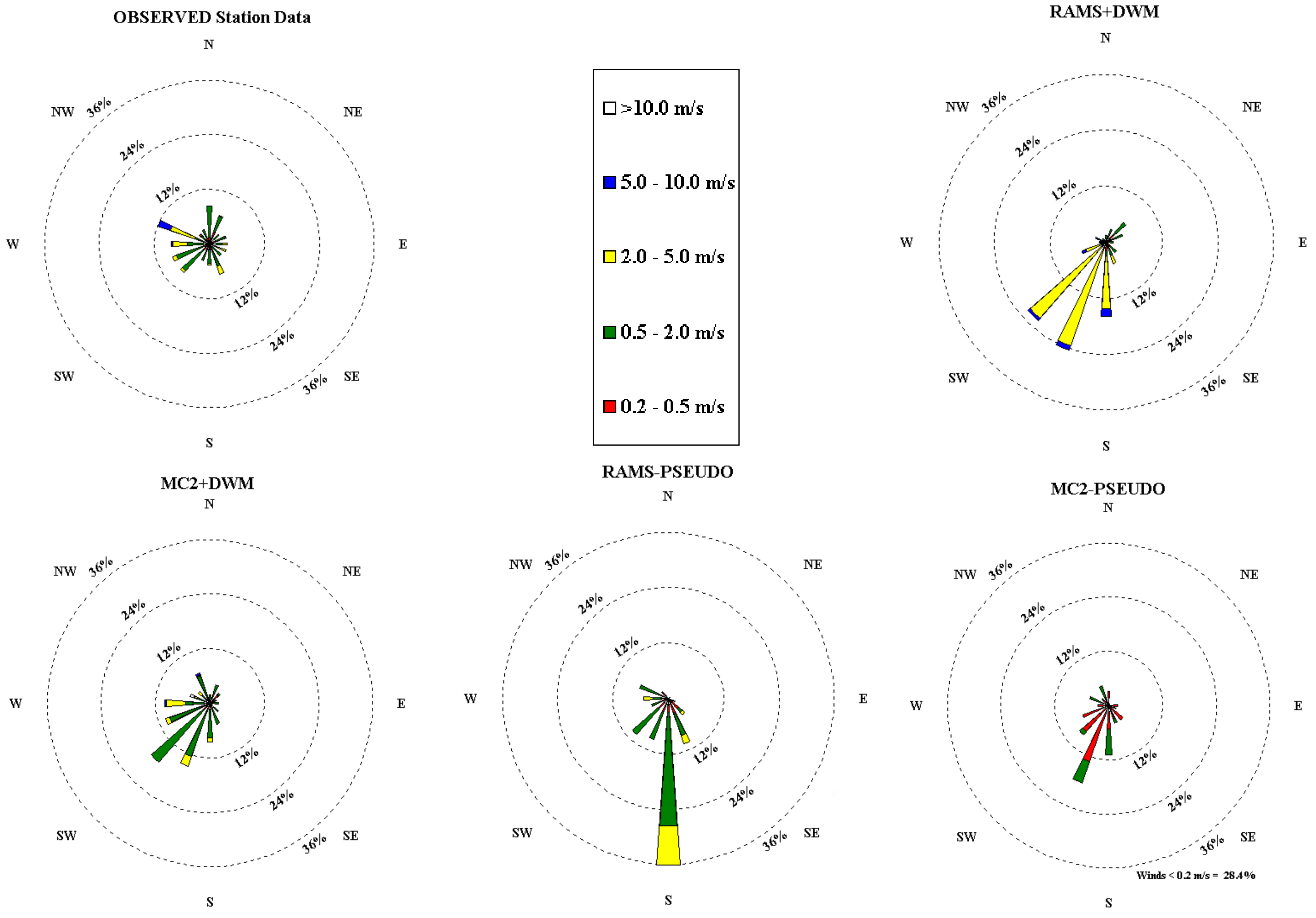


Winds < 0.2 m/s = 62.7%

Kamloops City (KAM1) Station



Kamloops City (KAM1) Station (continued)



APPENDIX B: Sample CALMET Input File

```
CALMET Input File used for BENCHMARK Simulation

--------------- 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=GEO.DAT       !
SURF.DAT      input    ! SRFDAT=sfc5.txt      !
CLOUD.DAT     input    * CLDDAT=            *
PRECIP.DAT    input    * PRCDAT=            *
MM4.DAT       input    * MM4DAT=            *
WT.DAT        input    * WTDAT=             *

CALMET.LST    output   ! METLST=CALMET.LST     !
CALMET.DAT    output   ! METDAT=CALMET.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=UPkel.txt!    !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=                  *
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=  2003  !
                     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=  336  !

     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 -- Map Projection and Grid control parameters
--------------

     Projection for all (X,Y):
     -------------------------

     Map projection
     (PMAP)                     Default: UTM    ! PMAP = UTM !

         UTM :  Universal Transverse Mercator
         TTM :  Tangential Transverse Mercator
         LCC :  Lambert Conformal Conic
         PS  :  Polar Stereographic
         EM  :  Equatorial Mercator
         LAZA:  Lambert Azimuthal Equal Area

     False Easting and Northing (km) at the projection origin
     (Used only if PMAP= TTM, LCC, or LAZA)
     (FEAST)                    Default=0.0     ! FEAST  = 0.0 !
     (FNORTH)                   Default=0.0     ! FNORTH = 0.0 !

     UTM zone (1 to 60)
     (Used only if PMAP=UTM)
     (IUTMZN)                   No Default      ! IUTMZN = 10 !

     Hemisphere for UTM projection?
     (Used only if PMAP=UTM)
     (UTMHEM)                   Default: N      ! UTMHEM = N !
         N   :  Northern hemisphere projection
         S   :  Southern hemisphere projection

     Latitude and Longitude (decimal degrees) of projection origin
     (Used only if PMAP= TTM, LCC, PS, EM, or LAZA)
     (RLAT0)                    No Default      ! RLAT0 = 40.0N !
     (RLON0)                    No Default      ! RLON0 = 74.0W !

         TTM :  RLON0 identifies central (true N/S) meridian of projection
                RLAT0 selected for convenience
         LCC :  RLON0 identifies central (true N/S) meridian of projection
                RLAT0 selected for convenience
         PS  :  RLON0 identifies central (grid N/S) meridian of projection
                RLAT0 selected for convenience
         EM  :  RLON0 identifies central meridian of projection
                RLAT0 is REPLACED by 0.0N (Equator)
         LAZA:  RLON0 identifies longitude of tangent-point of mapping plane
                RLAT0 identifies latitude of tangent-point of mapping plane

     Matching parallel(s) of latitude (decimal degrees) for projection
     (Used only if PMAP= LCC or PS)
     (XLAT1)                    No Default      ! XLAT1 = 35.0N !
     (XLAT2)                    No Default      ! XLAT2 = 45.0N !

         LCC :  Projection cone slices through Earth's surface at XLAT1 and XLAT2
         PS  :  Projection plane slices through Earth at XLAT1
                (XLAT2 is not used)

     ----------
     Note:  Latitudes and longitudes should be positive, and include a
            letter N,S,E, or W indicating north or south latitude, and
            east or west longitude.  For example,
            35.9  N Latitude  =  35.9N
            118.7 E Longitude = 118.7E


     Datum-Region
     ------------
```

```
     The Datum-Region for the coordinates is identified by a character
     string.  Many mapping products currently available use the model of the
     Earth known as the World Geodetic System 1984 (WGS-G ).  Other local
     models may be in use, and their selection in CALMET will make its output
     consistent with local mapping products.  The list of Datum-Regions with
     official transformation parameters provided by the National Imagery and
     Mapping Agency (NIMA).

     NIMA Datum-Regions  (Examples)
     ------------------------------------------------------------------------------
     WGS-G     WGS-84 GRS 80, Global coverage
     NAS-C     NORTH AMERICAN 1927 Clarke 1866, MEAN FOR (CONUS)
     NWS-27    NWS 6370KM Radius, Global Sphere (NAD27)
     NWS-84    NWS 6370KM Radius, Global Sphere (WGS84)
     ESR-S     ESRI REFERENCE Normal Sphere (6371KM Radius), Global Reference Sphere

     Datum-region for output coordinates
     (DATUM)                    Default: WGS-G     ! DATUM = WGS-G  !



     Horizontal grid definition:
     ---------------------------

     Rectangular grid defined for projection PMAP,
     with X the Easting and Y the Northing coordinate

            No. X grid cells (NX)      No default     ! NX =   240  !
            No. Y grid cells (NY)      No default     ! NY =   240  !

     Grid spacing (DGRIDKM)            No default     ! DGRIDKM = 0.250 !
                                       Units: km

     Reference grid coordinate of
     SOUTHWEST corner of grid cell (1,1)

        X coordinate (XORIGKM)         No default     ! XORIGKM = 644.750 !
        Y coordinate (YORIGKM)         No default     ! YORIGKM = 5590.650 !
                                       Units: km

     Vertical grid definition:
     -------------------------

        No. of vertical layers (NZ)    No default     ! NZ =  12  !

        Cell face heights in arbitrary
        vertical grid (ZFACE(NZ+1))    No defaults
                                       Units: m
        ! ZFACE = 0.,20.,50.,100.,200.,300.,400.,500.,800.,1000.,1500.,2000.,3300. !


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

       Print interval
       (IPRINF) in hours                  Default: 1     ! IPRINF =  12  !
       (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  !
       -----------------------


       Specify which levels of the W wind component to print
```

```
 (NOTE: W defined at TOP cell face --  6  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  !


 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  !

 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 =  0  !

    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 =  0  !

    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!


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

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


    NO OBSERVATION MODE             (NOOBS)  Default: 0     ! NOOBS = 0  !
          0 = Use surface, overwater, and upper air stations
          1 = Use surface and overwater stations (no upper air observations)
              Use MM5 for upper air data
          2 = No surface, overwater, or upper air observations
              Use MM5 for surface, overwater, and upper air data

    NUMBER OF SURFACE & PRECIP. METEOROLOGICAL STATIONS

       Number of surface stations   (NSSTA)  No default     ! NSSTA =  5  !

       Number of precipitation stations
       (NPSTA=-1: flag for use of MM5 precip data)
                                    (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 =  1  !
       (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 ,  -1 ,  0 ,  0.2, 0.5, 1, 1, 1, 1, 1  !


      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 = -1.0 !

      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]

      Timestep (hours) of the prognostic
      model input data   (ISTEPPG)          Default: 1      ! ISTEPPG = 1  !


   RADIUS OF INFLUENCE PARAMETERS

      Use varying radius of influence       Default: F      ! LVARY =  T!
      (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 = 5. !
                                            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 = 12. !

                                            Units: km
      Relative weighting of the first
      guess field and observations in the
      SURFACE layer (R1)                    No default      ! R1 = 5. !
      (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 = 200. !
      (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 = 54. !
      (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 =
4 ,  8 ,  8 ,  8, 8, 8, 8, 8, 8, 8, 8, 8  !

      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 =
10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10  !

      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. !
      (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 =  2  !
         (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., 1000. !
         (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 =  0 !
       (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

       3D temperature from observations or
       from prognostic data? (ITPROG)       Default:0         !ITPROG = 0 !

          0 = Use Surface and upper air stations
              (only if NOOBS = 0)
          1 = Use Surface stations (no upper air observations)
              Use MM5 for upper air data
              (only if NOOBS = 0,1)
          2 = No surface or upper air observations
              Use MM5 for surface and upper air data
              (only if NOOBS = 0,1,2)

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

       Radius of influence for temperature
       interpolation (TRADKM)               Default: 500.     ! TRADKM = 10. !
                                            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 = -0.0035 !
       above the mixing height over
       water (K/m) (TGDEFA)

       Beginning (JWAT1) and ending (JWAT2)
       land use categories for temperature                    ! JWAT1 =  55  !
       interpolation over water -- Make                       ! JWAT2 =  55  !
       bigger than largest land use to disable

   PRECIP INTERPOLATION PARAMETERS

       Method of interpolation (NFLAGP)      Default = 2    ! NFLAGP =  2  !
        (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 --  NSSTA  records in all)


             1     2
         Name   ID            X coord.   Y coord.   Time   Anem.
                               (km)       (km)      zone   Ht.(m)
       ----------------------------------------------------------
! SS1 = 'EC '    12341       680.072     5619.566    8    10  !
! SS2 = 'WLAP '    12342       683.603     5619.689    8    10  !
! SS1 = 'Wall '    12343       678.601     5600.482    8    10  !
! SS2 = 'Kam1 '    12344       685.749     5613.792    8    10  !
! SS1 = 'Kam2 '    12345       704.993     5613.106    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 --  NUSTA  records in all)

             1     2
         Name    ID      X coord.   Y coord.  Time zone
                           (km)       (km)
        -----------------------------------------------
! US1  ='KEL '  12345   733.281   5500.700      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 --  NPSTA  records in all)

            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!
```