On The Spatial Assessment of Forest Fire Smoke Exposure and Its Health Effects:

Part 1: Initialization of the CALMET Meteorological Model

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1.0 Introduction

During the fire season of 2003, more than 266 000 hectares of forest in British Columbia were consumed by wildfires. In comparison, only 8 581 ha burned in the province in 2002 and 76 574 ha were consumed in 1998, the latter being the worst fire season of the previous decade. Of the fires occurring in 2003, approximately 75% were in the relatively dry southern interior region of the province.[1] While the damage these widespread fires caused to the property of individuals and the commons was well-documented, less is known about the acute health effects of exposure to the extremely high levels of particulate matter witnessed during this time period.

This report is but a small component of a larger health study which seeks to assess the health effects of exposure to the wildfire smoke during the summer of 2003 in Southern Interior British Columbia. The study region, consisting of a population of approximately 638 800 people, is shown for reference in Figure 1.

Figure 1: Region of Interest for Health Study. The shaded area in the south-east corner of the province constitutes the study area.

The first stage of the health study will use the CALPUFF dispersion modelling system to arrive upon a spatially-variant estimate of exposure to particulate matter originating from wildfires in the region during the time period of interest. An important component of this project will, therefore, be the skilful initialization and parameterization of this modelling

[1] BC Ministry of Forests: Forest Fire Statistics, 2004

system. This document considers the initialization of the CALMET deterministic meteorological model which will be used to provide the meteorological inputs necessary to drive the CALPUFF dispersion model.

1.1 Study Objectives

This report considers three different methods of initializing the surface and upper-air fields in the CALMET meteorological model in the Okanagan region of South Interior BC for a two-week test period during the height of the fire season of 2003. The primary goal of this comparison is to determine an optimal initialization and parameterization of the model. The three general initialization strategies are:

1. Using prognostic data alone to initialize both the upper air and surface meteorological fields.

2. Relying on observed data alone to initialize CALMET's meteorological fields.

3. Using observed data from surface stations alongside upper-air fields extracted from prognostic data to initialize the CALMET model.

The three methods listed above will be referred to throughout this document, respectively, as the PROG, OBON, and COMB approaches. In addition to analysis of these three general initialization strategies, select model parameterizations affecting the way in which the surface and upper-air meteorological fields are assimilated into the CALMET model will be investigated.

1.2 On the Use of Prognostic Data in CALMET

As aforementioned, the CALPUFF modelling system is to play a key role in the larger study as it will be used to estimate daily exposure to wildfire smoke in different areas of Southern Interior British Columbia during the summer of 2003. This modelling system has evolved greatly since its creation in 1990, but at the core still consists of a meteorological model (CALMET), a transport and dispersion model (CALPUFF), and a post-processor to analyze modelling results (CALPOST).[2]

The CALMET meteorological model is what is typically used to provide the meteorological data necessary to initialize the CALPUFF dispersion model and is the focus of this study. The model is initialized with terrain and land-use data describing the region of interest, as well as meteorological input from potentially numerous sources. Various user-defined parameters control both how the input meteorological data is interpolated to the grid, as well as which internal algorithms are applied to these input fields. Output from the CALMET model includes hourly temperature and wind fields on

[2] CALPUFF User's Guide: http://www.src.com/verio/download/calpuff.pdf

a user-specified three-dimensional domain as well as additional two-dimensional variables used by the CALPUFF dispersion model.

CALMET has traditionally been initialized with meteorological inputs from surface stations within the region of interest as well as information from any nearby twice-daily radiosonde stations. However, as prognostic meteorological fields assimilated for forecasting are routinely archived by various groups, often at relatively high resolution, such data is now often used as input for the CALMET model.

The primary theoretical advantages of using prognostic data to help initialize CALMET include the following:

1. The sacristy of radiosonde stations means that upper-air meteorological fields must often be interpolated from locations up to 400 km away for certain CALMET applications. Subsequently, significant mesoscale circulations may not be well-represented in the model. Thus, if upper-air prognostic fields are accurate (which usually is not known due to this same scarcity of radiosonde stations), it can be argued that such data might benefit the run by providing upper-air meteorological input at a higher spatial resolution.

2. Similarly, for modelling in more remote locations without nearby surface stations, prognostic data can provide reasonable estimates of local surface meteorological conditions. This is a particularly important factor in regions of complex terrain, where the interpolation of fields such as surface winds from one valley system into another may not give realistic results due to factors such as valley orientation.

3. There may also be advantages in using prognostic data to initialize CALMET when the temporal resolution of input upper-air data is considered. While the radiosonde data historically used to initialize the model are available only at 12 hour increments, prognostic data can provide CALMET with more frequent (potentially sub-hourly) dynamically-balanced upper-air input.

The main caveat when using prognostic data to initialize CALMET is that one needs to ensure that such data is reasonably accurate. Most prognostic models have their own strengths and weaknesses and different models may perform better in a region with a specific type of terrain or under a specific set of synoptic conditions. Thus, when using prognostic data as input to CALMET, it is important that this data be treated with caution as it may not represent the physical reality.

2.0 Methodology

2.1 Modelling Domain

The domain selected for the initialization comparison was a subset of the larger region (Figure1) to be modelled for the health study. A smaller 125 000 sq km grid was chosen to cover the Okanagan Valley area, including the communities of Vernon, Kelowna, and Penticton (Figure 2 & Table 1).

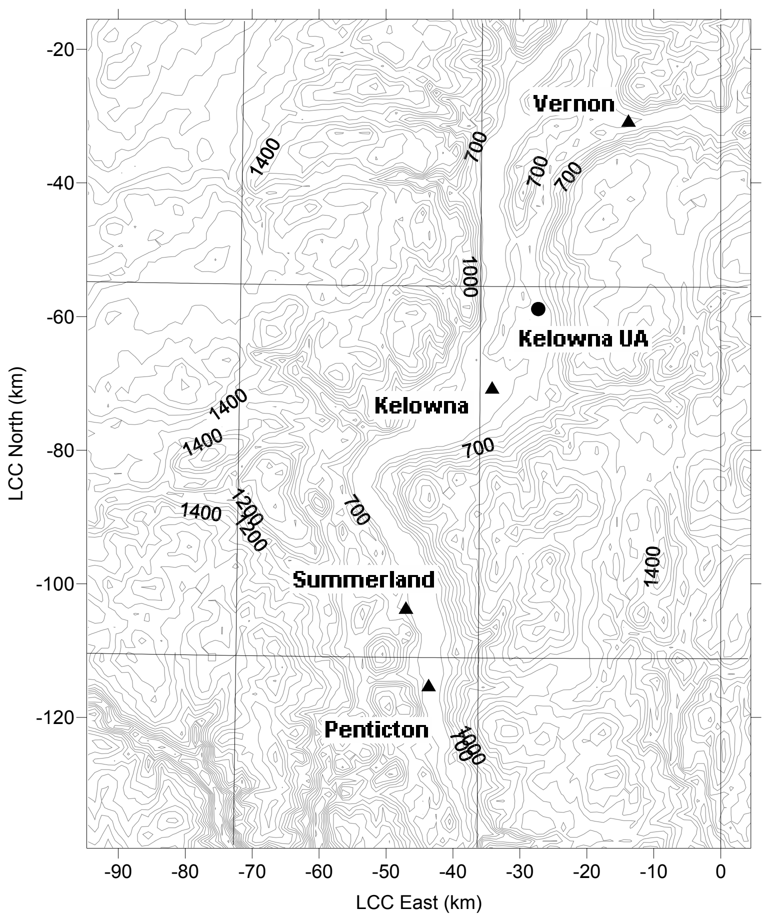


Figure 2: Modelling Domain. Contoured terrain and locations of input meteorological stations are shown as they fall within the bounds of the study domain. The four surface meteorological stations used for model initialization are represented by triangles; the location of the upper air station in Kelowna is represented by a circle. The coordinate system is a custom LCC projection as defined in Table 1.

The modelling domain shown in Figure 2 was chosen primarily because it contained a relatively high density of surface stations (for both model initialization and validation), as well as the only upper-air station in Southern Interior British Columbia. Furthermore, when compared to many of the other areas investigated in the health study, this region had a relatively high population density. Thus, the correct parameterization of meteorological inputs in the Okanagan region was considered particularly important to the accuracy of the modelling to be done for the larger health study.

Table 1: Map Projections and Horizontal Grid Parameters

Parameter	Value
Map Projection	Lambert Conformal Conic
False Easting, Northing	0 km, 0km
Projection Origin	50.5 N, 119.0 W
Matching Parallels of Latitude	51.5 N, 49.5 N
Datum	WGS-84
Number of Grid Cells (nx,ny)	100, 125
SW Corner (x,y)	- 95 km, -140 km
Grid Spacing	1 km

A locally-centered Lambert Conformal Conic projection was chosen to model the larger 325 000 sq km region considered for the health study (Table 1). This projection was chosen to minimize grid distortion as advised by the CALMET model's authors, Earth Tech.[3] This same projection was used for the smaller Okanagan sub-domain for consistency.

2.2 Data Sources and Treatment

2.2.1 Geophysical Data

Both land-use and terrain elevation data are necessary to initialize the CALMET model's geophysical file. For the Okanagan grid, terrain elevations were initialized with data from the Shuttle Radar Topography Mission (SRTM). This data, a preliminary product from a joint project between the US National Aeronautics and Space Administration (NASA) and the US National Geospatial-Intelligence Agency (NGA), is available at 3 arc-second (approximately 90 m) resolution for the continent of North America.[4] The SRTM data was then processed by the CALPUFF terrain pre-processor TERREL over the domain of interest.

Baseline Thematic Mapping (BTM) land-use data[5] was provided for this study by the British Columbia Ministry of Environment (BC MoE). The BTM data was provided in a polygonized format at a scale of 1:250 000, with a minimum polygon size of about 10 ha for most land-use categories. This data was re-projected to the LCC projection defined in

[3] See FAQs at http://www.src.com/calpuff/FAQ-answers.htm#1.1.5
[4] Data can be obtained at ftp://e0mss21u.ecs.nasa.gov/srtm/North_America_3arcsec/3arcsec/
[5] For more information or to order this product: http://srmwww.gov.bc.ca/dss/initiatives/ias/btm/index.htm

Table 1, then converted to a raster grid over the modelling domain. This information was then exported to a text format and converted into the fractional land-use format accepted by the CALMET MAKEGEO pre-processor. This conversion was accomplished by mapping the dominant BTM land-use category for each grid cell into one of the Level I (and in a few cases, Level II) US Geological Survey (USGS) land-use categories typically used in the CALMET model (Table 2).

Table 2: Mapping from BC to CALMET Land-Use Categories

BC Category	USGS Category	USGS Level	CALMET Code
Agriculture	Agricultural Land	I	20
Residential-Agricultural Mix	Agricultural Land	I	20
Alpine	Tundra	I	80
Sub-alpine Avalanche Shoots	Barren Land	I	70
Recent Burn	Forest Land	I	40
Old Forest	Forest Land	I	40
Young Forest	Forest Land	I	40
Recently Logged	Rangeland	I	30
Selectively Logged	Forest Land	I	40
Rangeland	Rangeland	I	30
Mining	Barren Land	I	70
Recreational Activities	Rangeland	I	30
Barren Land	Barren Land	I	70
Urban	Urban or Built-up Land	I	10
Shrub	Rangeland	I	30
Glacier	Perennial Snow or Ice	I	90
Wetlands	Non-forested Wetland	II	62
Fresh Water	Fresh Water	II	51
Estuaries	Bays and Estuaries	II	54
Salt Water	Salt Water	II	55

As the BC land-use categories are generally more descriptive than most of the default CALMET categories, the approximations made in the mapping defined by Table 1 appear legitimate. Note that CALMET Codes 51, 54, and 55 all have the same default physical properties defined in the MAKEGEO namelist file. Thus, any distinction between these categories is probably not relevant to this study.

The resultant fractional land-use file was then combined with the processed terrain data with the CALMET MAKEGEO pre-processor. This provided the geophysical file used to initialize all simulations done for this study.

2.2.2 Meteorological Data

Prognostic data at approximately 12 km[6] resolution was provided for use in this study by SENES Consultants Ltd. in a CALMET-ready format. This data was prepared by extracting the necessary meteorological fields from archived output of the US National Weather Service (NWS) / National Centers for Environmental Prediction (NCEP) 'Eta' model. This product, which has analysis fields available at 6-hour time intervals, uses a vertical coordinate system which may improve modelling over complex terrain such as that found in the study domain. Only one data fill was required: a missing 0Z Aug 27th entry was replaced with the 6Z analysis fields from same day.

Observed hourly-averaged meteorological data from surface stations during the modelling period was provided by Environment Canada (EC) and the BC MoE. As seen in Figure 2, these stations are all located in the Okanagan Valley. While the data from the EC Penticton station contained all fields necessary to initialize CALMET for the two-week period, the other stations were all either missing records for certain hours or did not monitor for some of the required input variables (Table 3).

Table 3: Surface Stations Properties

Station Name	Type	Latitude	Longitude	Elevation (m)	Missing CALMET Input
Kelowna	MoE & EC	49.864[7]	-119.475	300	Night-time Cloud Cover from 22:00 to 3:00 LST
Penticton	EC	49.463	-119.602	344	None
Summerland	EC	49.567	-119.65	454	Cloud Cover, Ceiling Height
Vernon	EC	50.224	-119.193	482	Cloud Cover, Ceiling Height

Hourly cloud and station pressure information was not recorded at the MoE Kelowna station. However, these variables were available from a nearby EC airport station, and, subsequently, were combined with the MoE Kelowna fields to provide more input data in this local area. It was decided that these cloud and pressure values should not be used alongside the other EC meteorological variables to define a distinct input surface station at Kelowna because EC wind instrumentation tends to be of lower precision than at MoE stations. Indeed, the inclusion of two Kelowna stations would have caused a dampening of the more accurate MoE signal in the interpolated CALMET surface winds.

Short sequential missing entries were filled for select meteorological variables in the surface station input file whenever possible.[8] For larger data gaps, fields were marked missing and were, subsequently, not included in the data assimilation during this time period. Hours with calm wind records were labelled 'missing' during the pre-processing.

[6] GRIB Grid ID #218: http://www.nco.ncep.noaa.gov/pmb/docs/on388/tableb.html#GRID218
[7] Note: The spatial location given for Kelowna is from the MoE station.
[8] Automated interpolation of singular missing values was done for wind-speed, relative humidity, temperature, station pressure, and cloud cover; consecutive missing values, as well as wind-direction and ceiling height, were assessed manually on an individual case-by-case basis.

Observed upper-air radiosonde data from Kelowna, available at 12-hour time intervals, was downloaded from the US National Oceanic and Atmospheric Administration's (NOAA) database[9] for the period of interest. Fields were then easily prepared for input by the CALMET READ62 pre-processor. The relative location of the Kelowna upper-air station, (49.97 N, 119.38 W), is denoted by the circle in Figure 2.

2.3 Model Parameterization

A 336 hour run commencing Aug 14th at 0:00 PST was initialized over the described modelling domain using three distinct methods. Each method corresponded to a particular 'mode' of running CALMET as specified by the NOOBS parameter in the model namelist file. Although each initialization strategy required that attention be paid to different model parameters, several key CALMET input options were common to all three simulations. Appendix B contains a sample CALMET input file used to initialize the COMB case. The model options selected for the other cases were, besides the alterations mentioned in the following sections, the same as those specified in this Appendix.[10]

Table 4: CALMET Vertical Levels

Level	Height at Top (m)
1	20
2	40
3	80
4	160
5	320
6	600
7	1000
8	1500
9	2200
10	3000
11	4000
12	5000

Twelve vertical levels were used to model the atmosphere up to a maximum cell face height of 5000 m (Table 4). Although emissions from forest fires may exceed this height, it was thought to be unlikely that the well-mixed particulate above the chosen maximum height would return to the ground in any significant concentration.

[9] Database access at http://raob.fsl.noaa.gov/
[10] For more information concerning CALMET model parameters, refer to CALMET user's guide: http://www.src.com/verio/download/calmet.pdf

The CALMET diagnostic wind module was applied, in all cases, to the 'Initial guess' field generated by the interpolation of the input wind data onto the three-dimensional model grid. This module treats the 'Initial guess' wind field with processes such as divergence minimization, blocking effects of terrain, and slope-flow algorithms to form the so-called 'Step 1' wind field. Model default options for the parameterization of this module were used in all simulations as no clear advantage was observed during the testing of alternative configurations.

One model parameter affecting the action of the diagnostic wind module is TERRAD, which specifies the radius of influence for terrain features. This variable was set to a value of 8 km to ensure that terrain effects up to the ridgeline would be seen for wider valleys, but would not be apparent across mountain ranges.

2.3.1 The PROG Case (NOOBS = 2)

This test case relied solely on the prognostic data from the Eta model at 12-km resolution to initialize CALMET. As aforementioned, this data was available at 6-hour increments spanning the simulation time.

Besides the previously discussed options concerning the diagnostic wind module, the only parameterization of interest in the PROG case concerned the initialization of cloud amounts in the model. As the standard prognostic data input format for the CALMET model does not allow for cloud cover information, this necessary input must be specified by either an external data file, or estimated from the prognostic 850 mb relative humidity fields. As this additional cloud information was not available, the latter option was utilized (ICLOUD = 3).

2.3.2 The OBON Case (NOOBS = 0)

Table 5: Radius of Influence Parameters

Parameter	Definition	Value (km)
R1	Distance from Surface Station at which Observation and Initial Guess Field are Equally Weighted for Surface Layer	8
R2	Same as R1, but for all Non-Surface Levels	8
RMAX1	Maximum Radius of Influence Over Land in the Surface Layer	25
RMAX2	Maximum Radius of Influence Over Land Aloft	25
RMAX3	Maximum Radius of Influence Over Water	25

This case used hourly surface station data as specified in Table 3 alongside the twice-daily upper-air fields from Kelowna to initialize CALMET. Running the model with this type of initialization strategy required more attention be paid to parameters that determine, in both the horizontal and in the vertical, how each station influences the wind field.

When CALMET is run with observed station data alone, an additional treatment of the wind field is performed following the diagnostic wind module. In brief, this involves a re-introduction of the original observed station data to the ‘Step 1’ wind field output from the diagnostic wind module. This is accomplished by a simple inverse-distance method specifying the radius of influence for signals from both upper-air and surface stations. Weighting factors (R1/2) as well maximum radii of influence parameters (RMAX1/2/3) control this interpolation process (see Table 5). These parameters were set to allow for station influence to dominate within the larger valley systems, as well as a gradual blending of these signals into the ‘Initial Guess’ field.

The extrapolation of surface winds within CALMET allows input surface station winds to have influence in the levels aloft. This option is especially useful for approximating winds that occur above ground but below ridgeline heights in complex terrain. In such cases, factors such as valley orientation and differential surface properties may cause the interpolation of above-ground winds from a potentially remote sounding station to give highly unrealistic estimates for certain locations. It should be noted that this surface extrapolation, if used, is applied to surface station values on two separate occasions with the CALMET model: during the creation of the ‘Initial Guess’ field, and, again when the observed data is reintroduced to the ‘Step 1’ wind field within the specified radii of influence.

Along with choices concerning the method of computation for this extrapolation (IEXTRP), the CALMET user is provided with an option to control, for each vertical level, the relative weighting (BIAS) of the extrapolated surface and upper-air values in the final interpolation. It is important to note here that this weighting is applied only for the first of the two cases in which extrapolation can be performed: during the creation of the ‘Initial guess’ field.

Table 6: Surface Wind Extrapolation Parameters

Parameter	Value	Default
IEXTRP	-4	Yes
BIAS	-1,-1,-1,-1,-.5,0,5,1,1,1,1,1	No
RMIN2	4 km	Yes
ICALM	0	Yes

For the OBON test case, the default method of extrapolation, using similarity theory and ignoring the influence of upper-air stations in the level-1 wind field, was applied. A BIAS configuration increasing the weighting of surface influence up to about 460 m was chosen to be a conservative estimate for valley-bottom to ridgeline heights in Southern Interior British Columbia. A summary of the model parameters chosen to control surface wind extrapolation is shown in Table 6.

For the OBON case, cloud data, when available, was obtained from the observed surface stations listed in Table 3. Thus, unlike the PROG case, observed cloud amount and ceiling height fields could be used to initialize CALMET.

2.3.3 The COMB Case (NOOBS = 1)

This final method of initialization was essentially a hybrid of the two aforementioned cases. Prognostic data was used, as in the PROG case, to create the 'Initial guess' wind field as well as provide upper-air data temperature data. However, input from the surface stations shown in Table 3 was also used, as in the OBON case, to initialize most surface variables as well as model cloud cover and ceiling height. The availability of cloud data for this case meant that, unlike the PROG case, internally-computed cloud amounts from the 850 mb relative humidity field were not required.

While the surface winds can not be used directly in the computation of the 'Initial Guess' when CALMET is run in this mode, these values are eventually merged with the 'Step 1' wind field, as described in the OBON case: within a specified radius of influence and, optionally, via extrapolation in the vertical direction. This allows for a limited, localized effect of surface stations in the final CALMET wind field. Note that while extrapolation of surface winds is permitted, the BIAS parameter has no effect when running CALMET in this mode; this is because the 'Initial Guess' wind field is derived completely from the prognostic data in this case. With the exception of this unused BIAS parameter, all radii of influence and extrapolation parameters for the COMB case were configured as shown in Tables 5 and 6.

Although prognostic data was used to initialize the temperature field in the levels aloft, it was decided that model level 1 temperatures should be initialized from surface station values only (ITPROG = 1). This method, while beneficial in allowing for more realistic surface temperature values, is severely limited as it does not allow the influence of this data to extend into the levels aloft. However, as the prognostic surface temperatures were often much lower than expected across the domain, this configuration was seen as the best possible option.

2.3.4 Alternate Parameterizations

While many different parameterizations and initialization strategies for CALMET were investigated over the course of this study, certain simulations provided particularly interesting results. Select results from these simulations will also be discussed in this report. All cases, besides NSFX, were simple modifications of the COMB case and were parameterized as follows:

1. PLAW: Power law extrapolation method (IEXTRAP = -2) used to extrapolate surface winds instead of the default 'similarity theory' technique.

2. NSFX: No surface extrapolation done, but for the OBON case (IEXTRAP = -1).

3. NCLOUD: Zero cloud amounts assigned for all stations for the duration of the simulation.

2.4 Validation and Metrics of Comparison

To help assess the accuracy of the simulation results, four BC Ministry of Forests (MoF) fire-weather stations, as shown in Table 7, were used to compare hourly model surface winds and temperatures to observed values. Summary statistics, error measure parameters,[11] as well as graphical methods formed the basis of comparison.

Table 7: MoF Surface Stations Used for Validation

Station Name	Latitude	Longitude	Elevation (m)	Within RMAX[12]
Penticton	49.518	-119.553	427	Yes
Stemwinder	49.380	-120.153	597	No
Brenda Mines	49.868	-119.993	1493	No
Fintry	50.207	-119.480	670	Yes

As usual, comparisons between observed station data and model output such as those made in this report should be interpreted with some caution. Criterion such as instrument siting; averaging methodology; instrumentation threshold, error, and resolution could all have caused the 'observed' data considered to be a less-than-ideal depiction of reality. In particular, the relatively low resolution of the wind instrumentation used at certain MoF stations such as Fintry and Penticton may have affected validation results.

Unfortunately, validation of model upper-air fields was not possible as it was necessary to use the only available radiosonde station in the initialization of the OBON case. Therefore, only the intercomparison of results from different simulations was possible for the layers aloft. Similarly, hourly output mixing heights computed by CALMET for each case could only be compared to one another.

Because of the general lack of validation data for this study, and, so that model sensitivities might be better understood, graphical techniques were applied extensively to investigate output from the cases of interest. Such approaches included investigating meteorological fields through time-series plots at discrete spatial locations as well as two-dimensional horizontal and vertical plots at specific time-steps. Wind-rose diagrams were used to help assess simulation differences as well as the general accuracy of model surface winds.

[11] Error measures used: Root Mean Square Error (RMSE), Absolute Difference (AD), and Pearson's Correlation Coefficient (r).

[12] Stations that lie within 25 km for at least one of the surface stations in OBON/COMB. For stations outside this radius, model wind output will be nearly identical for the PROG and COMB cases.

3.0 Simulation Results

3.1 Surface Winds

Table 8 summarizes the relative performance of the modelling of surface winds for the three initialization strategies at the four MoF validation stations. It should be noted while Penticton and Fintry fall within the radius of influence of at least one of the surface stations used to initialize the COMB and OBON test cases, Brenda Mines and Stemwinder should only see influence from the 'Initial Guess' field. Thus, for these latter stations, surface wind speeds are virtually identical in the PROG and COMB test cases, with values coming from only the prognostic data.

Table 8: Hourly Surface Wind Speed Summary Statistics [13]

Station	Case	μ	σ	Min	Max	AD	RMSE	r
Brenda Mines	COMB	3.34	1.89	0.24	10.97	1.91	2.44	0.05
	OBON	1.58	1.19	0.12	6.78	1.75	2.18	0.16
	PROG	3.37	1.89	0.34	10.95	1.91	2.45	0.05
n = 306[14]	OBS	2.81	1.56	0.00	7.92			
Fintry	COMB	3.19	1.78	0.22	8.53	1.99	2.46	0.47
	OBON	1.31	0.85	0.04	4.76	1.33	1.78	0.10
	PROG	3.74	2.05	0.19	8.51	2.47	3.02	0.43
n = 336	OBS	1.48	1.64	0.00	9.36			
Penticton	COMB	1.93	1.09	0.14	6.57	0.77	0.98	0.52
	OBON	2.37	1.41	0.42	10.05	0.90	1.20	0.63
	PROG	1.93	1.03	0.14	4.73	0.97	1.18	0.24
n = 336	OBS	1.86	0.88	0.00	5.08			
Stemwinder	COMB	2.40	1.16	0.08	5.86	1.54	1.81	-0.11
	OBON	2.04	1.45	0.07	9.34	1.43	1.78	0.20
	PROG	2.42	1.15	0.07	5.85	1.53	1.79	-0.10
n = 336	OBS	2.53	1.26	0.58	6.83			

[13] Units, for all measures besides 'r' are in m/s; 'OBS' = Observed MoF station values.
[14] Select model records were deleted to match hours with missing data for this station.

As shown in the Table above, mean model output surface winds stemming from prognostic data, in general, were higher than those coming from the OBON case. While these slightly stronger winds proved to be reasonable at Brenda Mines, Penticton and Stemwinder, they resulted in an unrealistic scenario at other stations such as Fintry. This trend may be due to the prognostic values themselves, but also could be a product of the interpolation of these fields to surface level during CALMET initialization.

While the lighter OBON wind speeds were fairly accurate at all four MoF stations, magnitudes were slightly underestimated at Brenda Mines, a station located about 40 km west of Kelowna. This underestimation shows the limitation of initializing the surface wind field in CALMET with the OBON method: in complex terrain, for regions far away from the surface stations used as input, the interpolated wind field may not be a great representation of reality.

This limitation is also apparent in the case of modelled wind directions. The windrose diagrams for Brenda Mines in Appendix A show that wind directions interpolated from the Okanagan valley in the OBON run lack the westerly component seen in the observed station values. On the other hand, the PROG run, initialized with data lacking the resolution to resolve the complex terrain, causes the flow at this location to be *more* westerly than observed. A similar pattern was seen across much of the surface wind field: while PROG surface winds remained more indicative of mesoscale or synoptic wind patterns, OBON wind directions were overly-biased toward the orientation of the Okanagan valley.

As is typical in many modelling studies, wind directions were relatively poorly represented, for all cases, during more stagnant meteorological conditions. During such times, the intrinsically high variance of the wind field can make the accurate *measurement*, let alone the accurate modelling, of wind directions a difficult task. Figure 3 shows that while wind directions at the Penticton MoF station were well modelled during a strong wind event on the afternoon of Aug 16th, accuracy during calmer wind conditions was less apparent in all simulations.

Figure 3 also is effective in showing the action of the COMB treatment of the prognostic 'Step 1' wind field with available observed surface station data. While the PROG winds may lack the resolution to model more localized circulations, the COMB approach allows for the addition of valuable local wind data. Indeed, the error measures shown in Table 8 suggest that for inside-radius-of-influence stations such as Penticton and Fintry[15], the surface stations used to initialize the COMB run improved the modelling of surface wind speeds when compared to the PROG case.

[15] Note that for both these MoF stations, wind instrumentation is not as accurate as at the other stations.

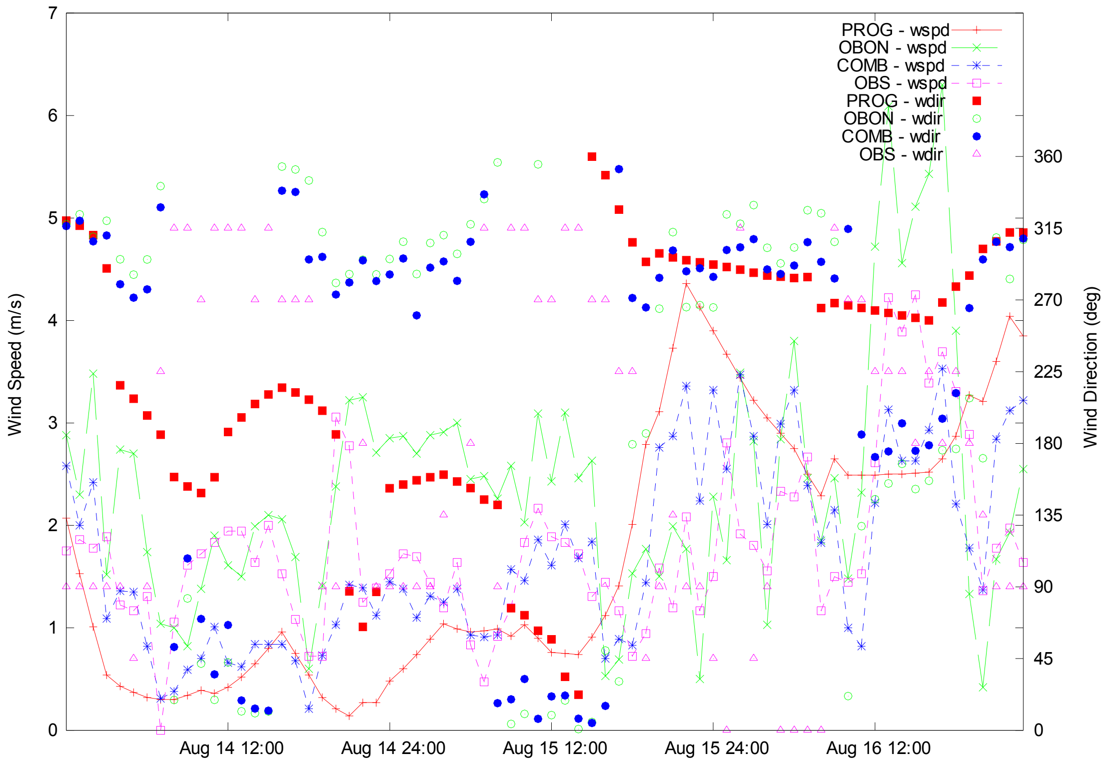


Figure 3: August 14-16 2003: Hourly Winds at Penticton MoF Station. Hourly observations are shown over 72 hours from August 14th 0:00 to August 16th 23:00 PST. 'Prog only' denotes the PROG simulation; 'Obs only' denotes the OBON simulation; 'Combined' denotes the COMB simulation; 'Observed' refers to MoF station values.

Table 8 shows that, for all initialization strategies, surface wind speeds were much more accurately modelled at Penticton-MoF than any other validation point. It should be noted that this is highly related to the relative proximity of this station to the Penticton EC station. While data from this station was used directly as input for both the COMB and OBON cases, surface wind measurements from this location were also very likely assimilated into the prognostic Eta fields used in the PROG and COMB cases. The superior correspondence seen, in all cases, at this location demonstrates a simple but important point: a better representation of the local reality in model output is highly dependent on a better representation of the local reality in model input.

3.2 Upper-Level Winds

As aforementioned, no independent upper-air data was available for proper validation of the above ground wind output from the three modelling strategies. However, as upper-level winds from the 'additional' NSFX case outlined in section 2.3.4 were completely determined from the radiosonde values, output from this simulation could be used to assess, for locations sufficiently near to Kelowna, the general accuracy of both the input prognostic data as well as surface extrapolations done by CALMET.

Figure 4 displays a snap-shot of the upper-level winds from PROG, COMB, and NSFX during a relatively calm period at Kelowna. As previously discussed, poor representation of near-surface wind directions during such times is a common modelling experience. The prognostic and surface-extrapolated values shown in Figure 4 are no exception. However, as height above ground increases, both PROG and COMB wind directions both converge upon the 'observed' NSFX values.

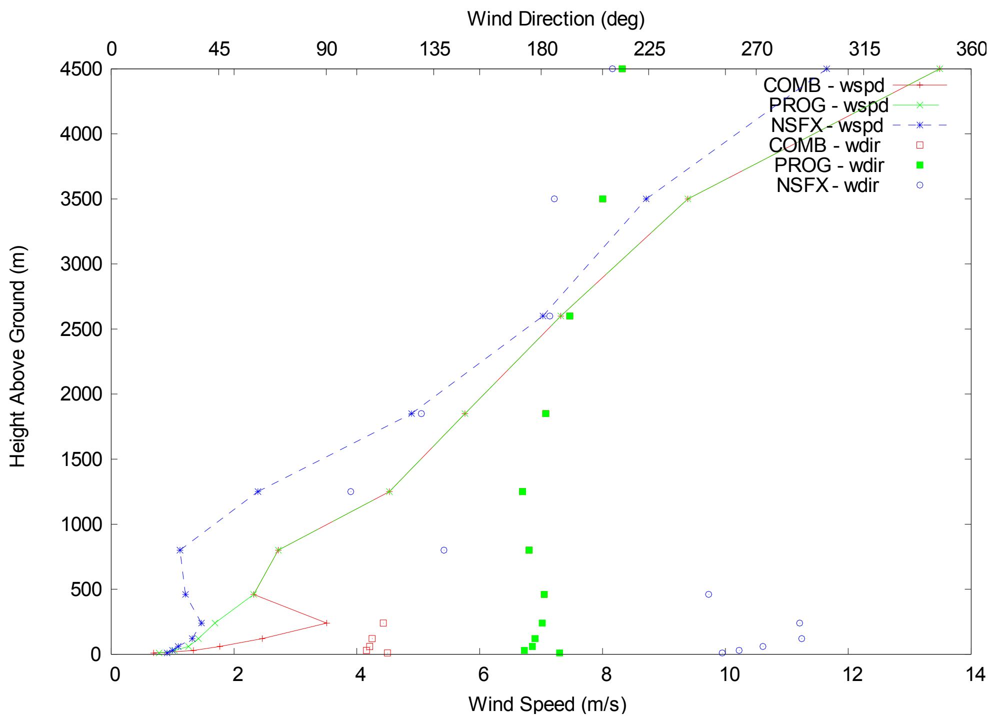


Figure 4: 12 UTC August 14 2003: Upper-level Winds at Kelowna. CALMET model output wind speeds and directions are shown at mid-cell heights for each vertical level defined in Table 4.

Although input prognostic fields, as suggested by Figure 4, showed generally good correspondence with the 'observed' NSFX radiosonde values, this is entirely expected at this location. This is because this same 'sounding' had already played a very important role in the initialization of the Eta fields used as input for the PROG and COMB cases.

Figure 4 also provides insight into the action of surface wind extrapolation in CALMET. As noted in section 2.3.3, the model default 'similarity theory' extrapolation was chosen for the COMB case. This method models the turning of the winds and estimates values aloft up to heights 200 m above the top of the model-estimated mixed layer. This upper limit to the extrapolation results is seen to be up to model level 5 for COMB in Figure 4. The plot also suggests that this extrapolation technique overestimates wind speeds in the layers aloft under certain circumstances. Further investigation into this matter revealed that the worst of these extrapolations occurred under lower wind speed conditions and predominantly at night. On the other hand, many of the extrapolations done during daytime hours and under periods of greater synoptic forcing resulted in much more reasonable near-surface wind field estimates.

3.2.1 Surface Wind Extrapolation

As surface wind extrapolation using the similarity theory technique gave, on certain occasions, highly erroneous estimates of wind speed up to 200 m above the top of the mixed layer, other model options were investigated. As outlined in section 2.3.4, the PLAW case provided more insight into the IEXTRAP option in CALMET.

Table 9: Summary of Level 4 Wind Speeds at Penticton[16] (n = 336)

Case	μ	σ	Min	Max	AD	RMSE	r
COMB	3.78	2.24	0.12	11.88	2.32	3.05	0.06
PROG	3.29	1.69	0.33	7.46	1.71	2.29	0.21
PLAW	2.95	1.66	0.25	9.68	1.70	2.31	0.08
NSFX	2.36	1.63	0.14	8.49			

Table 9 compares, for the COMB, PROG, and PLAW simulations, hourly CALMET level-4[17] wind speeds at the Penticton MoF station. While no 'true' validation data was available at this height, as Penticton shares a similar elevation, valley orientation, and spatial location with Kelowna, model output from the NSFX case was used as a sort of surrogate 'observation' for this comparison. The summary statistics show that the winds extrapolated in the PLAW case were much lower in magnitude than those estimated by the 'similarity theory' extrapolation done for the COMB case. Note that for both these cases, the level 4 winds at Penticton were also influenced by the prognostic field.

While the PLAW case provided level 4 wind speed estimates at Penticton which were more similar to the NSFX 'observations' than either the COMB or the PROG cases, some problems were encountered using this extrapolation technique. Figure 5 shows that, in certain circumstances, the extrapolation of lighter surface winds with the 'power law' technique can lead to the underestimation of wind magnitudes in the layers further aloft. Thus, while 'similarity theory' extrapolation is limited to heights just above the model mixed layer, the influence of 'power law' extrapolation extends all the way to the model top. While this characteristic, for most cases, does not result in an unrealistic upper-level wind field, it is a very important feature of this extrapolation that should be given attention.

[16] Units, for all measures besides 'r' are in m/s.
[17] Mid-cell height for this level is 120m.

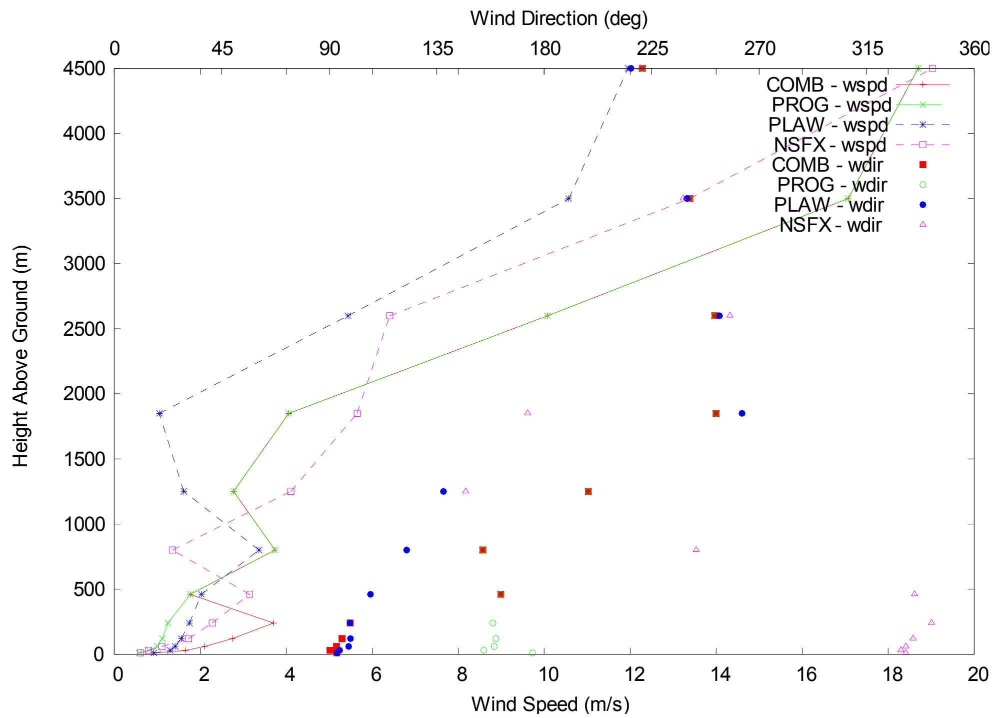


Figure 5: 12 UTC August 15 2003: Upper-level Winds at Kelowna. CALMET model output wind speeds and directions are shown at mid-cell heights for each vertical level defined in Table 4.

It should be noted that running CALMET in the COMB mode, but with no surface wind extrapolation, results in a very simplistic situation where input surface station data can only used to initialize the level 1 CALMET wind field. As the action of the input station winds is further restricted to within the specified radius of influence, the majority of model winds produced by this method will be identical to those from the PROG case.

3.3 Surface Temperatures

One of the major short-comings of the Eta prognostic data used in this study was a consistent underestimation of ambient temperatures, especially in layers closer to the ground. Table 10 gives an indication of the magnitude of these errors by comparing model output to hourly surface temperatures logged at the four MoF validation stations. On the other hand, OBON temperatures, with the exception of Brenda Mines, were relatively similar to the observed station values. Note that, since the COMB case was configured to use surface stations input to initialize the level-1 temperatures (ITPROG =1), results for this case were identical to those from the OBON simulation.

While the PROG surface temperatures were routinely lower than expected at all validation points, values were slightly more realistic at the station of highest elevation, Brenda Mines. Conversely, the least accurate surface temperature representation for the

OBON case was seen at this same location; warmer surface temperatures interpolated mostly from the lower-lying surface input stations in the Okanagan were probably to blame for this significant error.

Table 10: Hourly Surface Temperature Summary Statistics [18]

Station	Case	μ	σ	Min	Max	AD	RMSE	R
Brenda Mines	OBON	294.93	5.03	283.19	306.68	6.13	6.66	0.85
	PROG	286.04	4.32	277.71	299.15	3.18	3.78	0.88
n = 306	OBS	288.88	5.27	276.35	304.05			
Fintry	OBON	294.34	5.31	281.97	306.96	1.73	2.16	0.96
	PROG	288.72	4.52	277.08	301.05	7.20	7.76	0.79
n = 336	OBS	295.82	4.97	283.25	309.65			
Penticton	OBON	295.18	5.06	283.76	306.97	1.07	1.42	0.96
	PROG	290.52	4.22	281.03	301.05	5.07	5.95	0.75
n = 336	OBS	295.37	5.21	282.95	307.65			
Stemwinder	OBON	295.03	5.06	283.46	306.83	2.10	2.49	0.95
	PROG	286.68	4.60	278.05	300.55	7.89	8.79	0.80
n = 336	OBS	294.46	6.67	281.15	312.05			

It should be noted that although the PROG surface temperatures performed relatively poorly when compared to the OBON case with respect to accuracy, a more realistic variance was apparent in the two-dimensional surface temperature field for the former case. While the PROG temperatures varied with terrain heights, the OBON case, for many time periods, revealed a simple inverse-distance-weighted interpolation between the input surface station values.

3.4 Upper-Air Temperatures

Although no independent upper-air temperature validation data was available, as in section 3.2, model output from the PROG case could be compared to CALMET output from cases initialized with radiosonde data near to Kelowna to get a better notion of accuracy of the prognostic fields.

While CALMET contains model parameters that allow for the blending of surface wind values with the prognostic-data-originating 'Initial guess' winds in the COMB mode, no such option is available for the case of the temperature field. Subsequently, a very simplistic situation, in which surface stations alone are used to initialize model level 1

[18] Units, for all measures besides 'r' are in degrees Kelvin; 'OBS' = Observed MoF station values.

while all other levels are initialized with prognostic data, occurs.[19] This inability to effectively blend the input prognostic and surface station temperatures, when combined with the tendency of the prognostic data to underestimate ambient temperatures near the surface, resulted, in many instances, in a steep near-surface temperature gradient between the first two model levels (Figure 6).

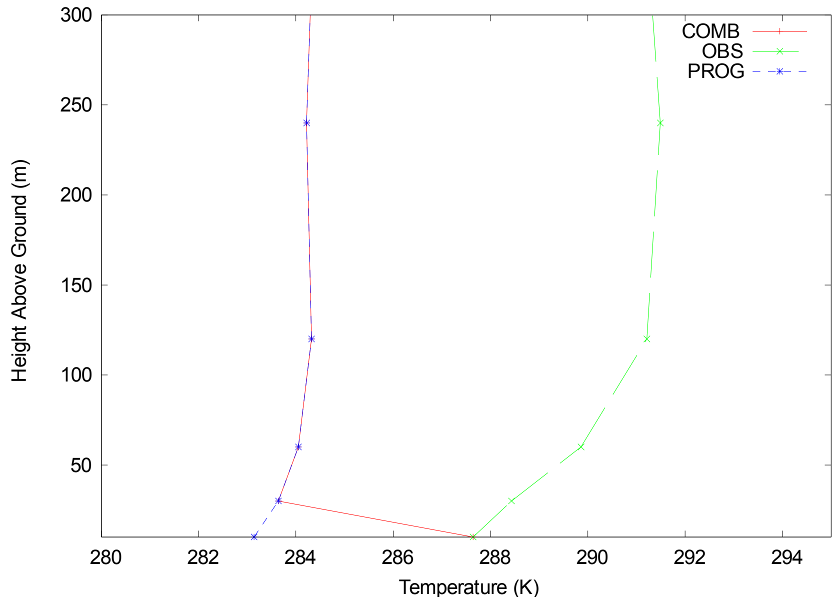


Figure 6: 12 UTC August 14 2003: Upper-level Temperatures at Kelowna. CALMET model output temperatures are shown at mid-cell heights for near-ground vertical levels.

Temperatures aloft in the PROG case, as suggested by Figure 6, tended to underestimate the 'observed' values seen in the OBON case, near Kelowna. While this trend was most apparent in the lowest levels of the atmosphere, it could, on certain occasions, be seen to extend all the way up to the model top. On the other hand, PROG vertical temperature gradients, important in model mixing height determination, were often quite similar, for locations near Kelowna and for heights greater than 50 m, to the 'observed' OBON values.

3.5 Mixing Heights

Daytime convective mixing heights estimated by the CALMET model are strongly dependent upon factors such as surface heat flux, stability, as well as the vertical temperature structure above the preceding hour's mixed layer. On the other hand, night-time mixing heights are largely derived from mechanical turbulence estimates which are highly dependent upon surface wind speeds. Up-wind effects of mixing heights at

[19] Note that this situation applies only to cases where model parameter ITPROG=1. The only other option when CALMET is run in the 'COMB' mode would be to set ITPROG=2, thus giving an identical temperature field to that seen in the PROG case.

adjacent cells as well as the previous hour's mixed layer depth are considered in both estimation processes.

As was the case with the upper-level wind and temperature fields, 'observed' mixing heights were not available to assess model estimates. Therefore, only the 'differences' seen between the different modelling strategies could be investigated. Table 11 shows a summary of these differences at each of the MoF station locations used for the surface wind and temperature comparisons.

Table 11: Hourly Mixing Height Summary Statistics[20] (n = 336)

Station	Case	μ	σ	Max	Min
Brenda Mines	COMB	838	537	2498	50
	OBON	600	634	2345	50
	PROG	893	611	2540	50
Fintry	COMB	930	516	2269	51
	OBON	543	576	2399	50
	PROG	1057	558	2260	52
Penticton	COMB	778	582	2035	50
	OBON	683	577	2252	50
	PROG	915	644	2557	50
Stemwinder	COMB	864	573	2614	50
	OBON	715	640	2568	50
	PROG	928	658	2770	50

The values in Table 11 show that, at all points of comparison, COMB average mixing heights are lower than the corresponding PROG values, but greater than means from the OBON case. While this trend was, in part, due to factors influencing daytime mixed layer growth such as surface heat flux, further investigation revealed that many of the differences occurred at night, and, therefore, were probably due to different surface wind speed estimates for the three cases. Figure 7 shows examples of such differences in model-estimated night-time mixing heights occurring at Fintry. Recall Table 8 showed wind speeds at this location to be more overestimated by the PROG case than at any other validation point. Figure 7 shows the effect that these higher prognostic-data-originating wind speeds had on night-time mixing heights. Note how night-time mixing heights for the COMB case, under the influence of the dampening of the surface wind signal from Vernon, are effectively reduced at this point of interest. It should be noted as well that mixing heights from the different test cases, as shown in Table 11, show more

[20] Units, for all measures are in meters.

difference at this location than at any other 'station' investigated. Thus, the influence of night-time surface winds upon modelled mixing heights was probably less important at many other locations.

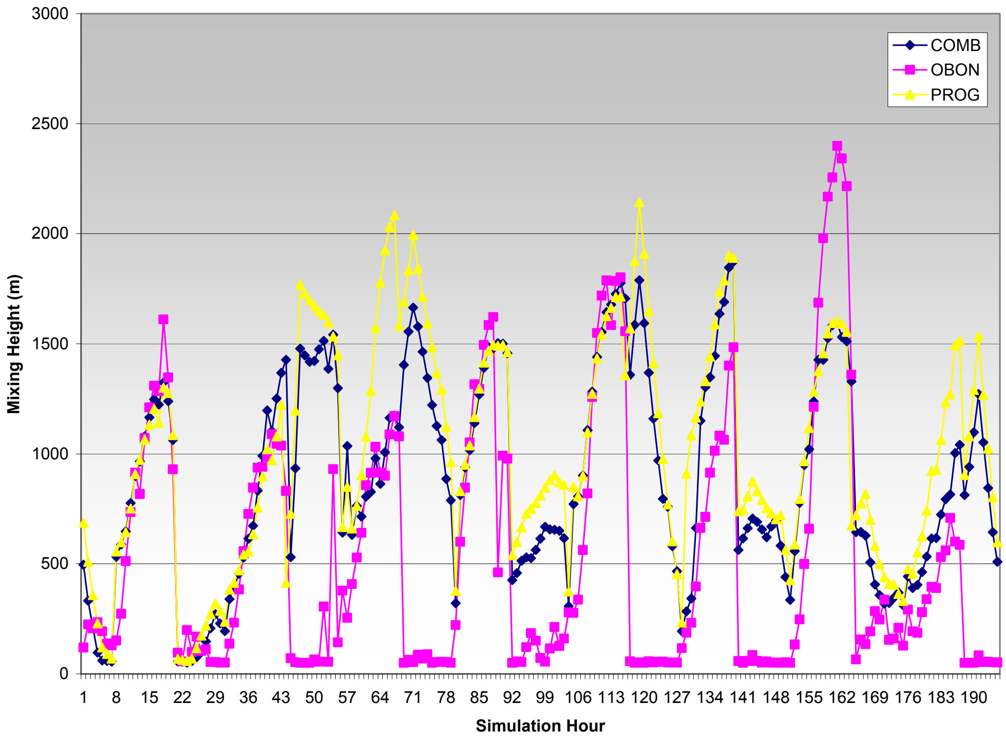


Figure 7: August 14-20 2003: Hourly Mixing Heights at Fintry. Hourly observations are shown over 7 days from August 14th 0:00 to August 20th 23:00 PST.

In general, differences in daytime convective mixing seen in the three simulations contributed less to the overall differences seen in Table 10 than did night-time values. However, differences in cloud cover amounts, vertical temperature profiles aloft, as well as surface wind strength still allowed for some significant differences to be seen in the mixing heights estimated by each test case.

3.5.1 Cloud Cover Effects

Daytime convective mixing heights in CALMET respond to differences in cloud amount, as demonstrated by the NCLOUD case. Table 12 shows how mixing heights at Brenda Mines and Sidewinder responded to the assignment of zero cloud amounts at all surface stations used as input in the COMB case. These points of comparison were chosen so that model winds and upper-level temperatures were virtually identical for the PROG and COMB cases. Note that differences in model surface temperatures remained between the two initialization strategies.

The summary statistics shown in Table 12 demonstrate that CALMET mixing heights responded to changes in cloud amount in the COMB case under different amounts of incoming shortwave radiation. Furthermore, NCLOUD summary statistics appear more similar to PROG values than to those from the COMB case. This suggests that the PROG run likely estimated a very negligible cloud cover amount from the 850 mb relative humidity field. This, in turn, suggests that the internal CALMET algorithms for calculating cloud amount for prognostic data were probably not very accurate for this test case.[21]

Table 12: Clouds and Hourly Mixing Heights[22] (n = 336)

Station	Case	μ	σ	Max	Min
Brenda Mines	COMB	838	537	2498	50
	PROG	893	611	2540	50
	NCLOUD	892	599	2518	50
Stemwinder	COMB	864	573	2614	50
	PROG	928	658	2770	50
	NCLOUD	929	646	2709	50

In addition, Table 12 shows that model surface temperatures probably do not play a very important role in mixing height determination. While the NCLOUD and PROG cases took very different surface temperatures as input (see Table 10), mixing height summary statistics for these cases are markedly similar. Further testing confirmed that although CALMET mixing heights do show *some* response to differences in model surface temperatures, this effect is much less important than some of the other influences discussed in this section.

[21] Such inaccuracies have also been observed in other modeling studies. See for example, the following report prepared for the BC MoE: http://wlapwww.gov.bc.ca/air/airquality/pdfs/calpuff.pdf

[22] Units, for all measures are in meters.

4.0 Discussion

Results from the investigation of model winds provide a good justification for using the COMB approach. While the prognostic data was clearly not sufficiently resolved to capture some of the more local terrain-driven circulations, it probably provided a better 'Initial guess' field than the interpolation from often-remote station locations utilized for the OBON case. While the COMB case incorporated this superior 'background' representation of model winds, it also allowed for local optimization of the prognostic wind field via the addition of surface station input. Additional upper-air data and the ability for CALMET to assimilate such fields while running in the COMB mode would allow for further optimization of model winds. Finally, the incorporation of accurate higher-resolution prognostic data would also clearly be of great benefit.

The extrapolation of surface winds should almost always be applied when running CALMET in the COMB mode. If this option is not utilized, the influence of input surface station winds will only affect the level-1 model winds, and, as such, will not play a very significant role in determining the dispersion of pollutants. The results of this study suggest that the 'power-law' approach should be considered instead of the default 'similarity theory' technique, especially under more stagnant meteorological conditions and at night. For either method, more control over the extrapolation procedure through the use of a parameter such as the BIAS setting for the OBON mode would allow for more optimal mid-level wind estimates.

The PROG initialization strategy consistently underestimated ambient temperatures, at both the surface, as well as in the levels aloft. The poor blending of these prognostic-data-originating temperatures with the input surface station values in the COMB case resulted in an unrealistic near-surface temperature gradient. However, as all of this occurred below the 50 m minimum mixing height specified by the model ZIMIN(W) parameter, it probably had very little influence on model mixing heights, and, subsequently, would probably have very little effect upon CALPUFF dispersion.

Although the simulations done in this study would clearly have benefited from more accurate prognostic fields, the assimilation of more accurate surface temperatures from surface stations in the COMB case allowed for the correction of the level 1 temperature field. A more sophisticated blending/extrapolation of these surface values with the input prognostic temperature data within CALMET would allow for this influence to extend beyond the first level, and would be a useful feature in CALMET.

The ability to incorporate observed cloud data into model input was shown to be another advantage of using the COMB approach instead of PROG. As cloud amount plays a significant role in the determination of model mixing heights, and as the current method of estimating cloud amounts using the PROG method is probably not very accurate, a more optimal initialization will be achieved through the inclusion of this observed data.

5.0 Recommendations

It should be noted that this study investigated model behaviour over a mere two week period, and for but a sub-domain of the larger study area shown in Figure 1. Thus, while the test cases were chosen to investigate a region of significantly complex terrain, and, over a time period containing a variety of meteorological conditions, the results of this preliminary study many not apply to all regions, for certain periods modelled in the larger health study. With this in mind, the following recommendations are proposed here for the CALMET production runs which are to be done for the larger health study:

1. An initialization strategy similar to the COMB approach (as in Appendix B), using observed data from surface stations alongside upper-air fields extracted from prognostic data, should be used to initialize CALMET.

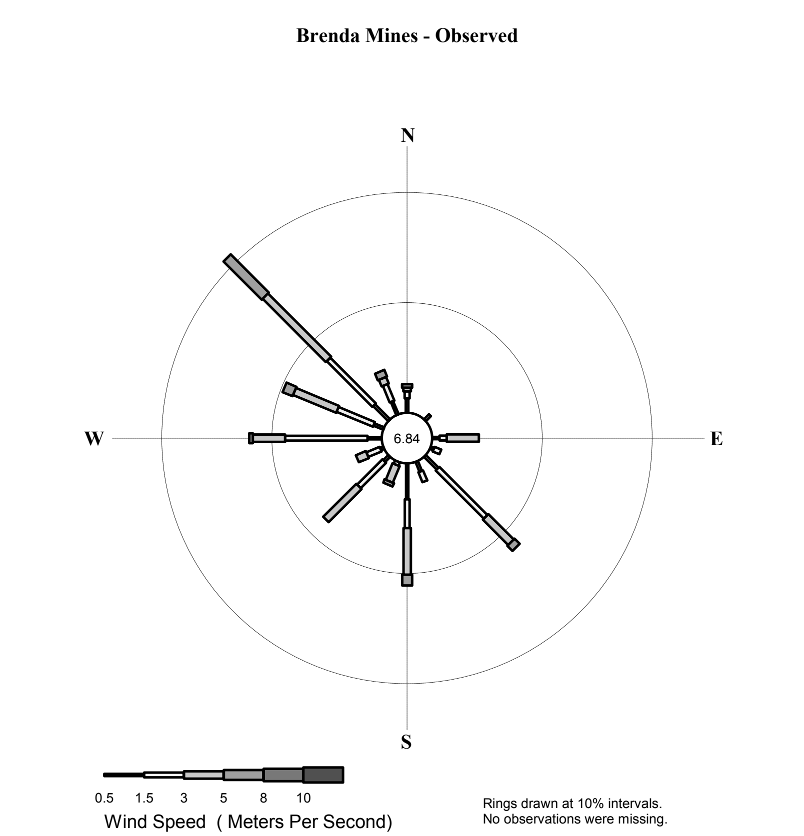
2. The ‘power law’ method should be used to extrapolate surface winds instead of the model-default similarity theory approach.

3. Model surface temperatures, as in the COMB case, should be extracted from surface station values as the available prognostic data appears to significantly underestimate ambient temperatures.

4. Additional observed surface data, from stations such as the ones used for validation in this study, will provide a more accurate depiction of local conditions than will the prognostic data. Thus, all available surface data of sufficient quality should be assimilated into the input for the production runs.

Appendix A: Windrose Plots – Brenda Mines

The following windrose diagrams depict the frequency of winds occurring from different directions and in different speed classes for hourly data as extracted from CALMET, and, as logged by the MoF wind instrumentation at Brenda Mines. The frequency of 'calm' winds, defined to be less than 0.5 m/s for these plots, is shown in the center of each windrose. Note that the winds from the COMB case are virtually identical to PROG at Brenda Mines station.



PERCENT OCCURRENCE: Wind Speed (Meters Per Second)
LOWER BOUND OF CATEGORY

DIR	0.5	1.5	3	5	8	10
N	1.30	0.65	0.33	0.33	0.00	0.00
NNE	0.00	0.00	0.00	0.00	0.00	0.00
NE	0.65	0.00	0.00	0.00	0.00	0.00
ENE	0.00	0.00	0.00	0.00	0.00	0.00
E	0.65	0.65	2.93	0.00	0.00	0.00
ESE	0.33	0.65	0.00	0.00	0.00	0.00
SE	1.63	6.19	3.26	0.65	0.00	0.00
SSE	0.98	0.98	0.00	0.00	0.00	0.00

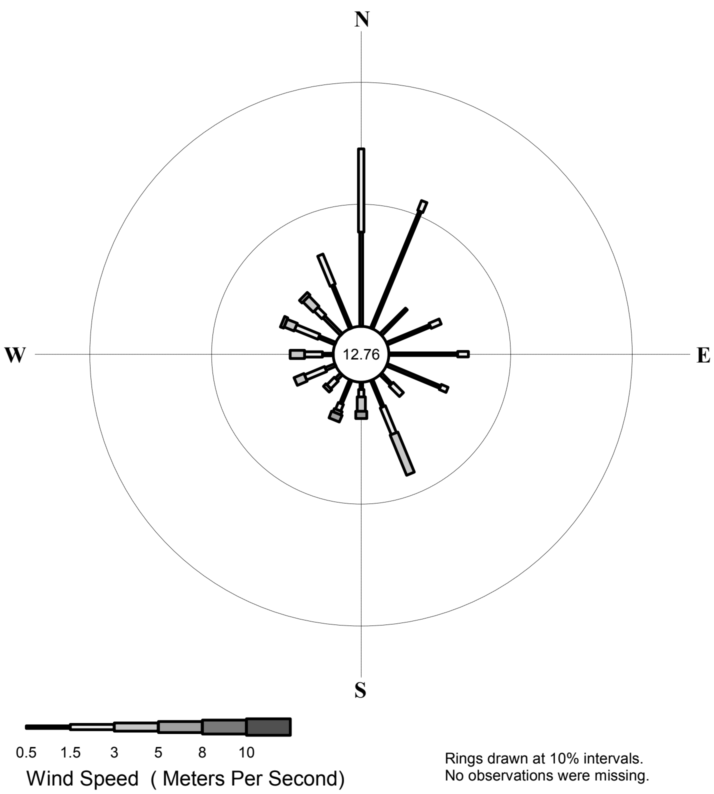
TOTAL OBS = 307 MISSING OBS = 0

PERCENT OCCURRENCE: Wind Speed (Meters Per Second)
LOWER BOUND OF CATEGORY

DIR	0.5	1.5	3	5	8	10
S	3.26	2.61	4.23	0.98	0.00	0.00
SSW	0.00	0.33	1.63	0.33	0.00	0.00
SW	0.65	3.26	4.23	0.00	0.00	0.00
WSW	0.33	1.30	0.98	0.00	0.00	0.00
W	1.30	7.49	2.93	0.33	0.00	0.00
WNW	0.98	3.58	4.23	0.98	0.00	0.00
NW	1.95	5.86	8.14	4.89	0.00	0.00
NNW	1.30	1.63	0.65	0.65	0.00	0.00

CALM OBS = 21 PERCENT CALM = 6.84

Brenda Mines - OBON



PERCENT OCCURRENCE: Wind Speed (Meters Per Second)
LOWER BOUND OF CATEGORY

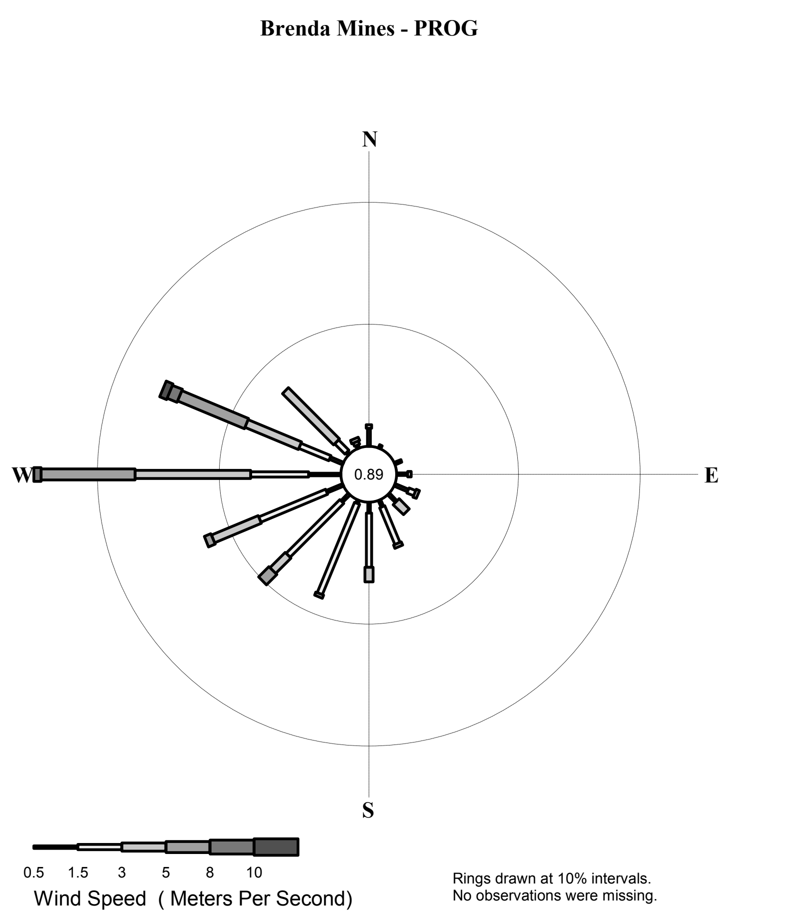
DIR	0.5	1.5	3	5	8	10
N	7.72	6.82	0.00	0.00	0.00	0.00
NNE	10.39	0.89	0.00	0.00	0.00	0.00
NE	2.97	0.00	0.00	0.00	0.00	0.00
ENE	3.86	0.89	0.00	0.00	0.00	0.00
E	5.64	0.89	0.00	0.00	0.00	0.00
ESE	4.75	0.59	0.00	0.00	0.00	0.00
SE	1.19	1.19	0.00	0.00	0.00	0.00
SSE	2.37	2.37	3.56	0.00	0.00	0.00

TOTAL OBS = 337 MISSING OBS = 0

PERCENT OCCURRENCE: Wind Speed (Meters Per Second)
LOWER BOUND OF CATEGORY

DIR	0.5	1.5	3	5	8	10
S	0.59	0.59	1.19	0.59	0.00	0.00
SSW	2.08	0.59	0.30	0.59	0.00	0.00
SW	0.59	0.89	0.30	0.00	0.00	0.00
WSW	0.89	1.78	0.89	0.00	0.00	0.00
W	0.89	1.48	1.19	0.00	0.00	0.00
WNW	1.48	2.08	0.89	0.30	0.00	0.00
NW	2.08	0.89	1.19	0.30	0.00	0.00
NNW	3.86	2.67	0.00	0.00	0.00	0.00

CALM OBS = 43 PERCENT CALM = 12.76



PERCENT OCCURRENCE: Wind Speed (Meters Per Second)
LOWER BOUND OF CATEGORY

DIR	0.5	1.5	3	5	8	10
N	1.48	0.30	0.00	0.00	0.00	0.00
NNE	0.30	0.00	0.00	0.00	0.00	0.00
NE	0.00	0.00	0.00	0.00	0.00	0.00
ENE	0.59	0.00	0.00	0.00	0.00	0.00
E	0.89	0.30	0.00	0.00	0.00	0.00
ESE	1.19	0.59	0.30	0.00	0.00	0.00
SE	0.89	0.00	1.19	0.00	0.00	0.00
SSE	0.59	3.26	0.30	0.00	0.00	0.00

TOTAL OBS = 337 MISSING OBS = 0

PERCENT OCCURRENCE: Wind Speed (Meters Per Second)
LOWER BOUND OF CATEGORY

DIR	0.5	1.5	3	5	8	10
S	0.89	4.45	1.19	0.00	0.00	0.00
SSW	0.30	8.01	0.30	0.00	0.00	0.00
SW	0.89	6.23	1.78	1.19	0.00	0.00
WSW	1.48	5.93	4.15	0.59	0.00	0.00
W	2.67	4.75	9.50	7.72	0.59	0.00
WNW	1.19	2.67	4.75	5.93	0.89	0.59
NW	0.30	1.19	5.93	0.00	0.00	0.00
NNW	0.30	0.30	0.30	0.00	0.00	0.00

CALM OBS = 3 PERCENT CALM = 0.89

Appendix B: Sample CALMET Input File (COMB)

----------- FILE STARTS ON NEXT LINE ---

```
combined


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

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

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

INPUT GROUP: 0 -- Input and Output File Names


Subgroup (a)
------------
Default Name  Type          File Name
------------  ----          ---------
GEO.DAT       input    ! GEODAT=C:\BENJAMIN\CALMET\INTERC~1\GEO_PREP\GEO.DAT       !
SURF.DAT      input    ! SRFDAT=C:\BENJAMIN\CALMET\INTERC~1\INIT_OBS\SURF.DAT      !
CLOUD.DAT     input    * CLDDAT=             *
PRECIP.DAT    input    * PRCDAT=             *
MM4.DAT       input    ! MM4DAT=E:\ETA-12~1\T39-ET~1     !
WT.DAT        input    * WTDAT=              *

CALMET.LST    output   ! METLST=COMBINED.LST     !
CALMET.DAT    output   ! METDAT=COMBINED.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 = F !
         F = UPPER CASE

NUMBER OF UPPER AIR & OVERWATER STATIONS:

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

                       !END!
--------------------------------------------------------------------------------
Subgroup (b)
---------------------------------
Upper air files (one per station)
---------------------------------
Default Name  Type       File Name
------------  ----       ---------
--------------------------------------------------------------------------------
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=  8  !
                       Day (IBDY) -- No default       ! IBDY=  14  !
                      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 = LCC  !

    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  = 0.000  !
(FNORTH)                   Default=0.0     ! FNORTH = 0.000  !

UTM zone (1 to 60)
(Used only if PMAP=UTM)
(IUTMZN)                   No Default      ! IUTMZN = -999   !

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 =  50.5N  !
(RLON0)                    No Default      ! RLON0 =  119W  !

    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 =  51.5N  !
(XLAT2)                    No Default      ! XLAT2 =  49.5N  !

    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-84).  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 is provided by the National Imagery and
     Mapping Agency (NIMA).

     NIMA Datum - Regions(Examples)
     ------------------------------------------------------------------------------
     WGS-84    WGS-84 Reference Ellipsoid and Geoid, Global coverage (WGS84)
     NAS-C     NORTH AMERICAN 1927 Clarke 1866 Spheroid, MEAN FOR CONUS (NAD27)
     NAR-C     NORTH AMERICAN 1983 GRS 80 Spheroid, MEAN FOR CONUS (NAD83)
     NWS-84    NWS 6370KM Radius, Sphere
     ESR-S     ESRI REFERENCE 6371KM Radius, Sphere

     Datum-region for output coordinates
     (DATUM)                    Default: WGS-84    ! DATUM = WGS-84  !


     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 =   100  !
            No. Y grid cells (NY)      No default     ! NY =   125  !

     Grid spacing (DGRIDKM)            No default     ! DGRIDKM = 1. !
                                       Units: km

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

        X coordinate (XORIGKM)         No default     ! XORIGKM = -95.000 !
        Y coordinate (YORIGKM)         No default     ! YORIGKM = -140.000 !
                                       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.,40.,80.,160.,320.,600.,1000.,1500.,2200.,3000.,4000.,5000. !

!END!


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

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


    DISK OUTPUT OPTION

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

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

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

```
LINE PRINTER OUTPUT OPTIONS:

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

   Print interval
   (IPRINF) in hours                   Default: 1     ! IPRINF =  1  !
   (Meteorological fields are printed
    every  1  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 =  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0  !
   -----------------------


   Specify which levels of the W wind component to print
   (NOTE: W defined at TOP cell face --  12  values)
   (IWOUT(NZ)) -- NOTE: NZ values must be entered
   (0=Do not print, 1=Print)
   (used only if LPRINT=T & LCALGRD=T)
   -----------------------------------
                                       Defaults: NZ*0
    ! IWOUT =  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  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 =  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0  !

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


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

  !  STABILITY  =           0           ! - PGT stability class
  !  USTAR      =           0           ! - Friction velocity
  !  MONIN      =           0           ! - Monin-Obukhov length
  !  MIXHT      =           0           ! - Mixing height
  !  WSTAR      =           0           ! - Convective velocity scale
  !  PRECIP     =           0           ! - 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 =  2  !


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

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

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

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

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

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

         Print the FINAL wind speed and direction
         fields ?
         (IPR3) (0=no, 1=yes)             Default: 0       !  IPR3 =  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 =  1   !
          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 =  4  !

       Number of precipitation stations
       (NPSTA=-1: flag for use of MM5 precip data)
                                    (NPSTA)  No default     ! NPSTA =  0  !

    CLOUD DATA OPTIONS
       Gridded 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
       ICLOUD = 3 - Gridded cloud cover from Prognostic Rel. Humidity

    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 =  2  !
       (1 = unformatted - CALMET unformatted output)
       (2 = formatted   - free-formatted CALMET output or user input)

!END!


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

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


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

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

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

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

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

       Extrapolate surface wind observations
       to upper layers ? (IEXTRP)            Default: -4     ! IEXTRP = -4  !
       (1 = no extrapolation is done,
        2 = power law extrapolation used,
        3 = user input multiplicative factors
```

```
            for layers 2 - NZ used (see FEXTRP array)
        4 = similarity theory used
        -1, -2, -3, -4 = same as above except layer 1 data
            at upper air stations are ignored

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

       Layer-dependent biases modifying the weights of
       surface and upper air stations (BIAS(NZ))
         -1<=BIAS<=1
       Negative BIAS reduces the weight of upper air stations
         (e.g. BIAS=-0.1 reduces the weight of upper air stations
       by 10%; BIAS= -1, reduces their weight by 100 %)
       Positive BIAS reduces the weight of surface stations
         (e.g. BIAS= 0.2 reduces the weight of surface stations
       by 20%; BIAS=1 reduces their weight by 100%)
       Zero BIAS leaves weights unchanged (1/R**2 interpolation)
       Default: NZ*0
                               ! BIAS = -1 , -1 , -1 , -1 , -.5 ,  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 = 4.0 !

       Use gridded prognostic wind field model
       output fields as input to the diagnostic
       wind field model (IPROG)              Default: 0      ! IPROG =  14  !
       (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 =  6   !

    RADIUS OF INFLUENCE PARAMETERS

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

       Maximum radius of influence over land
       in the surface layer (RMAX1)          No default      ! RMAX1 = 25. !
                                             Units: km
       Maximum radius of influence over land
       aloft (RMAX2)                         No default      ! RMAX2 = 25. !
                                             Units: km
       Maximum radius of influence over water
       (RMAX3)                               No default      ! RMAX3 = 25. !
                                             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 = 8. !

                                         Units: km
       Relative weighting of the first
       guess field and observations in the
       SURFACE layer (R1)                No default      ! R1 = 8. !
       (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 = 8. !
       (R2 is applied in the upper layers  Units: km
       in the same manner as R1 is used in
       the surface layer).

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

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

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

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

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

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

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

       Multiplicative scaling factor for
       extrapolation of surface observations
       to upper layers (FEXTR2(NZ))      Default: NZ*0.0
       ! FEXTR2 = 0., 0., 0., 0., 0., 0., 0., 0., 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 =  1  !
      (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   =  0  !
      (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 =  1  !
                                        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 =  1   !

      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 = 500. !
                                        Units: km

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

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

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

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

       Beginning (JWAT1) and ending (JWAT2)
       land use categories for temperature                    ! JWAT1 =  999  !
       interpolation over water -- Make                       ! JWAT2 =  999  !
       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 = 100. !
        (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 = 0.01 !
        (values < CUTP = 0.0 mm/hr)
!END!


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

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

     SURFACE STATION VARIABLES
     (One record per station --  4  records in all)


            1     2
         Name   ID            X coord.   Y coord.   Time   Anem.
                               (km)       (km)      zone   Ht.(m)
       ----------------------------------------------------------
! SS1  ='KEL'       1       -34.148      -70.625    8    10  !
! SS2  ='PEN'      14       -43.640     -115.156    8    10  !
! SS3  ='SUM'      15       -47.018     -103.560    8    10  !
! SS4  ='VER'      22       -13.771      -30.679    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 --  0  records in all)

            1     2
         Name    ID      X coord.   Y coord.  Time zone
                           (km)       (km)
        ----------------------------------------------
```

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

      2
        Five digit integer for station ID

!END!


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

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

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

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


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

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

!END!
```

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