Modeling Report for a BART Assessment of the Big Stone I Coal-Fired Power Plant, Big Stone City, South Dakota

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1. INTRODUCTION

TRC Environmental Corporation has conducted a site-specific BART (Best Available Retrofit Technology) modeling assessment of the Big Stone I coal-fired power plant facility located near Milbank and Big Stone City in South Dakota to determine if this facility is subject to BART controls on emissions. This report is a modeling assessment of baseline impacts from the Big Stone I power plant facility to determine whether the Big Stone I cyclone-fired boiler is subject to BART.

On July 6, 2005 the U.S. Environmental Protection Agency (U.S. EPA) published in the Federal Register the "Regional Haze Regulations and Guidelines for Best Available Retrofit Technology (BART) Determinations" (40 CFR Part 51). The regional haze rule requires States to submit implementation plans (SIPs) to address regional haze visibility impairment in 156 Federally-protected parks and wilderness areas, commonly referred to as "Class 1 Areas". The final rule addresses BART-eligible sources, which are defined as sources that have the potential to emit 250 tons or more of a visibility-impairing air pollutant, were put in place between August 7, 1962 and August 7, 1977 and whose operations fall within one or more of 26 specifically listed source categories, of which Coal-Fired Power Plants are one.

In January 2009, a modeling protocol was submitted by TRC for the Big Stone I BART modeling based on the use of fine scale meteorological modeling, MM5 data and hourly surface meteorological observations. In response to comments received from Environmental Protection Agency (EPA) and the Federal Land Managers (FLMs), a revised protocol was submitted in June 2009, proposing the use of higher resolution MM5 data with the EPA-recommended modeling input parameters. Based on further discussions with EPA, the FLMs and South Dakota Department of Environment and Natural Resources (DENR), subsequent revisions were made to the June protocol on August 31, 2009. DENR approved the revised protocol in a letter dated September 18, 2009. The modeling described in this report is consistent with the DENR's approved protocol (except as noted below) and is based on the emissions data described in the June 2009 TRC protocol along with the August 2009 revisions to incorporate EPA-recommended model switch settings and meteorological configuration. The exceptions to the protocol include the use of MNITRATE=0 instead of MNITRATE=1 in POSTUTIL for the baseline runs and the use of MNITRATE=3 for a set of alternative runs. See Section 3.4 for a more detail discussion. Also, the variable IUTMZN referred to in the EPA-recommended list of variables was not assigned because that variable is not used when using a Lambert Conformal projection.

The purpose of the modeling is to assess the visibility impacts of sulfur dioxide (SO_2), particulate matter (PM) and nitrogen oxides (NO_x) emissions from the Big Stone I boiler and compare the impacts to the 0.5 change in deciview threshold at all the federally mandatory Class I areas. Since there is no Class I area within the 300 km radius usually applied, the South Dakota Department of Environment and Natural Resources requested that the Class I areas between 300 km and up to 625 km away from the Big Stone I facility sources be modeled. A total of eight Class I areas are located between these distances: two wilderness areas: Boundary Waters Canoe Area Wilderness and Rainbow Lake Wilderness, one National Wildlife Refuge (NWR): Lostwood and five National Parks: Voyageurs NP, Theodore Roosevelt NP, Badlands NP, Wind Cave NP and Isle Royale NP. However, Rainbow Lake Wilderness is one of two Class I areas where the visibility analysis is not required (http://www.dnr.state.wi.us/org/aw/air/modeling/ psd.htm), so it is not included in the modeling analysis. The MM5 datasets distributed by WRAP did not extend far enough in the East to include the Isle Royale NP or cover all of the Boundary Waters Class I area. The re-extracted MM5 data for 2002 and new MM5 domains for 2006 and 2007 include these areas.

The CALMET and CALPUFF non-steady-state models (Scire et al., 2000a,b) are recommended by the U.S. EPA (*Federal Register*, 6 July 2005) to perform source-specific subject-to-BART screening. The CALPUFF system was therefore used for this modeling analysis. The U.S. EPA has promulgated the CALPUFF modeling system as a *Guideline Model* for Class I impact assessments and other long range transport applications or near field applications involving complex flows (U.S. EPA, 2000), and the model is recommended by both the Federal Land Managers (FLM) Air Quality Workgroup (FLAG, 2000) and the Interagency Workgroup on Air Quality Modeling (IWAQM, 1998). The CALPUFF modeling system is also recommended in new proposed guidance by the FLMs (FLAG, 2008). On August 31, 2009 EPA issued new recommendations on CALMET switch settings. The current modeling is based on the August 2009 recommendations.

The Big Stone I BART modeling analysis was performed with the EPA-approved Version 5.8 of the CALMET and CALPUFF models. Version 6.221 of CALPOST was used because it contains the FLM-approved implementation of Method 8 (FLAG, 2008), but in other respects is identical to the EPA-approved Version 5.6394.

CALMET is a diagnostic meteorological model that produces three-dimensional wind fields based on parameterized treatments of terrain effects such as slope flows and terrain blocking effects. Normally, meteorological observations are blended with gridded data from the NCAR-PSU Mesoscale Model, Version 5 (MM5). For this evaluation, MM5 data were generated by TRC with a 12-km grid spacing for two years (2006 and 2007) to define the initial guess wind fields. For 2002, 12-km MM5 data were re-extracted from the EPA MM5 dataset to cover entire region including the Isle Royale NP to the east.

CALPUFF is a non-steady-state puff dispersion model. It accounts for spatial changes in the CALMET-produced meteorological fields, variability in surface conditions (elevation, surface roughness, vegetation type, etc.), chemical transformation, wet removal due to rain and snow, dry deposition, and terrain influences on plume interaction with the surface. CALPUFF contains a module to compute visibility effects, based on a humidity-dependent relationship between particulate matter concentrations and light extinction, as well as wet and dry acid deposition fluxes. The meteorological and dispersion modeling simulations were conducted for three years (2002, 2006 and 2007). SO_2, SO_4, PM, and NO_x, emissions and their secondary products resulting from chemical conversions from the Big Stone I facility were modeled and their impacts on visibility evaluated at receptors in the Class I areas. Visibility impacts were estimated with the new

FLM-recommended visibility algorithm and monthly average relative humidity adjustment factors (Method 8 in Version 6.221).

This report outlines the techniques and data sources used in the BART analyses. In Section 2, a general description of the source configuration is provided. Descriptions of the site characteristics and data bases (meteorological, geophysical, and aerometric) are provided in Section 3. Section 4 includes an overview of the CALMET and CALPUFF models settings and parameters that were used in the analysis. The results are summarized in Section 5.

2. SOURCE DESCRIPTION

The 450-megawatt Big Stone I facility is a coal-fired power plant situated close to Big Stone City and Milbank in Grant County, South Dakota, at the border of Minnesota State. A BART applicability analysis was completed for the facility to determine those sources subject to the BART controls. The BART-eligible source is the Big Stone I cyclone-fired boiler with one stack 152 meters (498 feet) high.

The proposed emissions for the BART analysis were described in a Modeling Protocol dated June 2009. These emissions were reviewed and approved by SD DENR. Table 2-1 shows the source parameters and emission rates for the source considered in this report. The highest 24-hour average actual emission rates of SO_2, NO_x and PM under normal conditions over the 2001-2003 period were used for this analysis. As shown in Table 2-2, the filterable PM_{10} are divided into a particle size distribution based on AP-42, Table 1.1-6 for baghouse controlled emissions because the facility currently uses a fabric filter for PM control. Approximately 57.6% of the filterable mass is in the fine ($PM_{2.5}$) size category, and 42.4% in the coarse (2.5 to 10 µm diameter) size range. Each of the particle size categories was modeled as a separate PM species in CALPUFF. The filterable PM_{10} emission rate is reported by the facility at 10.48 g/s (83.2 lb/hr). Based on AP-42 Table 1.1-5, the total condensable PM_{10} is approximately 0.01 lb/mmBtu based on approximately 0.4% sulfur coal or 7.07 g/sec (56.1 lb/hr) assuming an heat input of 5609 mmBtu/hr. This estimate is consistent with the stack test data (August, 2006) at Otter Tail Power's Hoot Lake Plant, Unit 2, (which burns PRB coal) where the ratio of the filterable/total PM_{10} was 0.66, resulting in a 2/3 filterable and 1/3 condensable split to the total PM_{10}.[1]

Elemental Carbon (EC) emissions were assumed to be 3.7% of the fine filterable fraction based on U.S. EPA (2002) and were assigned to the smallest particle size category. The primary H_2SO_4 emissions are 0.454 g/s (3.604 lb/hr) based on annual emission inventories and Toxic Release Inventory reports. The remaining condensable emissions were assigned to organic carbon and distributed equally into the two smallest particle size categories.

Table 2-3 provides a summary of the PM_{10} speciation and size distribution.

Note that since all Class I areas are more than 50 km away from the facility, as recommended by the Federal Land Managers (FLMs) (US Fish and Wildlife, National Park Service and U.S. Forest Service), no downwash computations was performed.

[1] AP-42 Table 1.1-8 was not used to estimate the particulate matter size distribution for Big Stone I because the emission factors were derived for cyclones burning bituminous coal, not sub-bituminous coal which is burned at Big Stone I.

Table 2-1: Point Source Parameters and Emission Rates

Source	LCC[1] East (km)	LCC[1] North (km)	Stack Ht (m)	Base Elevation (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp. (K)	SO_2 Emission Rate (g/s)	H_2SO_4 Emission Rate (g/s)	NO_x Emission Rate (g/s)	Filterable PM_{10} Emission Rate (g/s)	Condensable PM_{10} Emission Rate (g/s)
Main Stack	38.141	587.875	151.79	328.90	7.37	20.14	423.00	608.9	0.454	611.7	10.48	7.07

[1] Lambert Conformal Projection with an origin of 40.0N, 97.0W and standard parallels at 33N and 45N. Datum is NWS-84.

Table 2-2: PM_{10} Size Distribution1

Particle Size[2] (μm)	Cumulative Mass (PM) (%)	Cumulative Mass (PM_{10}) (%)
15	97	-
10	92	100
6	77	83.7
2.5	53	57.6
1.25	31	33.7
1.00	25	27.2

1 From AP-42, Table 1.1-6, Cumulative particle size distribution and size-specific emission factors for dry bottom boilers burning pulverized bituminous and subbituminous coal.

2 Expressed as aerodynamic equivalent diameter.

Table 2-3: PM_{10} Speciation and Size Distribution

input Data:							H_2SO_4	**PM_{10}**	$PM_{2.5}$			
							g/s	**g/s**	g/s			
PM_{10} and H_2SO_4 Emissions (g/s)							0.454	**17.550**	13.106			
				filterable						**condensable**		
condensable %				**59.7%**						**40.3%**		
				g/s						g/s		
				10.480						7.070		
										non H_2SO_4 condensable		
										g/s		
										6.616		
			AP-42, Table 1.1-6									
	coarse	coarse	soil	soil	soil	soil	EC	H_2SO_4	OC	OC	IC (soil)	IC (soil)
	PM800	PM425	PM187	PM112	PM081	PM056	PM056		PM081	PM056	PM081	PM056
	6.00 - 10.00	2.50-6.00	1.25-2.50	1.00-1.25	0.625-1.00	0.50-0.625	0.50-0.625		0.625-1.00	0.50-0.625	0.625-1.00	0.50-0.625
	16.3%	26.1%	23.9%	6.5%	12.0%	15.2%	57.6%		50.0%	50.0%	50.0%	50.0%
EC % of filterable					**96.3%**		**3.7%**		**100%**		**0%**	
inorganic % of	g/s	g/s	g/s	g/s	g/s	g/s	g/s	g/s	g/s	g/s		
condensable	1.708	2.735	2.412	0.656	1.211	1.534	0.223	0.454	3.308	3.308		
	inputs to POSTUTIL:											
Extinction coefficient	0.6	0.6	1	1	1	1	10	3*f(RH)	4	4		
	coarse	**coarse**	**soil**	**soil**	**soil**	**soil**	**EC**	**H_2SO_4**	**OC**	**OC**		
	PM800	**PM425**	**PM187**	**PM112**	**PM081**	**PM056**	**PM056**		**PM081**	**PM056**		
	g/s	**g/s**	**g/s**	**g/s**	**g/s**	**g/s**	**g/s**	**g/s**	**g/s**	**g/s**		
	1.708	**2.735**	**2.412**	**0.656**	**1.211**	**1.534**	**0.223**	**0.454**	**3.308**	**3.308**		

3. GEOPHYSICAL AND METEOROLOGICAL DATA

The South Dakota Department of Environment and Natural Resources requested that the eight Class I areas shown in Figure 3-1 be considered in the BART analysis. Rainbow Lake Wilderness is one of two Class I areas where the visibility analysis is not required so it has been removed from the present analysis (see http://www.dnr.state.wi.us/org/aw/air/modeling/psd.htm). The MM5 dataset for this analysis were extended to include the Isle Royale National Park as well as all of the Boundary Waters Class I area.

3.1 Terrain

The topography of the domain area consists of terrain increasing toward the southwest from approximately 300 meters at the facility to 900 meters at Badlands NP and 1200 meters at Wind Cave NP, resulting in 900 meters (~3,000 feet) of terrain relief. The terrain relief also increases towards the northeast. The terrain gets mountainous on the west side of the facility near Badlands and Wind Cave National Parks.

Gridded terrain elevations for the refined modeling domain were derived from 3 arc-second digital elevation models (DEMs) produced by the United States Geological Survey (USGS). Data are provided in files covering 1 degree by 1 degree blocks of latitude and longitude. The 1-degree DEMs are produced by the Defense Mapping Agency using cartographic and photographic sources. USGS 1:250,000 scale topographic maps are the primary source of 1-degree DEMs.

One degree DEM data consists of an array of 1201 by 1201 elevations referenced on the geographic (latitude/longitude) coordinate system of the World Geodetic System 1972 Datum. Elevations are in meters relative to mean sea level, and the spacing of the elevations along each profile is 3 arc-seconds, which corresponds to a spacing of approximately 90 meters. For the North part of the east domain and north west domain covering the south side of Manitoba and Ontario, Canada, SRTM-3 data with also an approximate resolution of 90 meters were used.

The MM5 simulations conducted at 12-km grid spacing covering the modeling domain were used as initial guess field. CALMET was run at the 4-km resolution.

The USGS elevation records located within each grid cell in the computational domain are averaged to produce a mean elevation at each grid point. The CALPUFF computational domain is the same as the CALMET domain. The CALMET and CALPUFF domains extend at least 50 km beyond the Class I areas in order to provide an adequate buffer zone at the boundaries, and to allow the effects of flow curvature and possible small-scale recirculation to be evaluated.

3.2 Land Use

The Composite Theme Grid (CTG) land use data from the USGS, at a resolution of approximately 90m were processed to produce gridded fields of dominant land use categories for each grid cell. For the northern part of the domain covering Canada (south part of Manitoba and Ontario), 900 meters Global USGS land use data were also incorporated using a mesh density for sampling of 2.

Land use data are first processed to produce fractional land use categories. The 37 USGS land use categories are then mapped into 14 CALMET land use categories. Surface properties such as albedo, Bowen ratio, roughness length, and leaf area index are computed proportionally to the fractional land use. The USGS land use categories are described in Table 3-1. Table 3-2 displays the 14 CALMET land use categories and their associated geophysical parameters. Figure 3-2 shows the dominant land use categories used in the modeling.

3.3 Meteorological Data Base

The CALMET model has the ability to assimilate meteorological information from surface stations, precipitation stations, buoy data and upper air stations. Specifically, CALMET uses surface observations of wind speed, wind direction, temperature, cloud cover, ceiling height, surface pressure, relative humidity, and precipitation type (e.g., snow, rain, etc.). These variables are routinely measured at the National Weather Service (NWS) surface stations and were directly included on an hourly basis into CALMET. Upper air observations however are only available twice-daily at a few stations throughout the domain. The locations of the upper air stations in and around the region of interest, and used in the modeling, are displayed in Figure 3-3.

The surface, buoy and precipitation stations that were included in the modeling are displayed in Figure 3-4. For 2002, there are 272 surface stations, 2 buoys and 265 precipitation stations available with similar numbers in 2006 and 2007. Observed cloud cover and ceiling height from the surface meteorological stations were used in the analysis.

The three-dimensional gridded data from the prognostic numerical model MM5 with nested grids of 36-km, 12-km grid spacing were generated by TRC for 2006 and 2007. Information about the MM5 model configuration and an evaluation of model performance are provided in Appendix B.

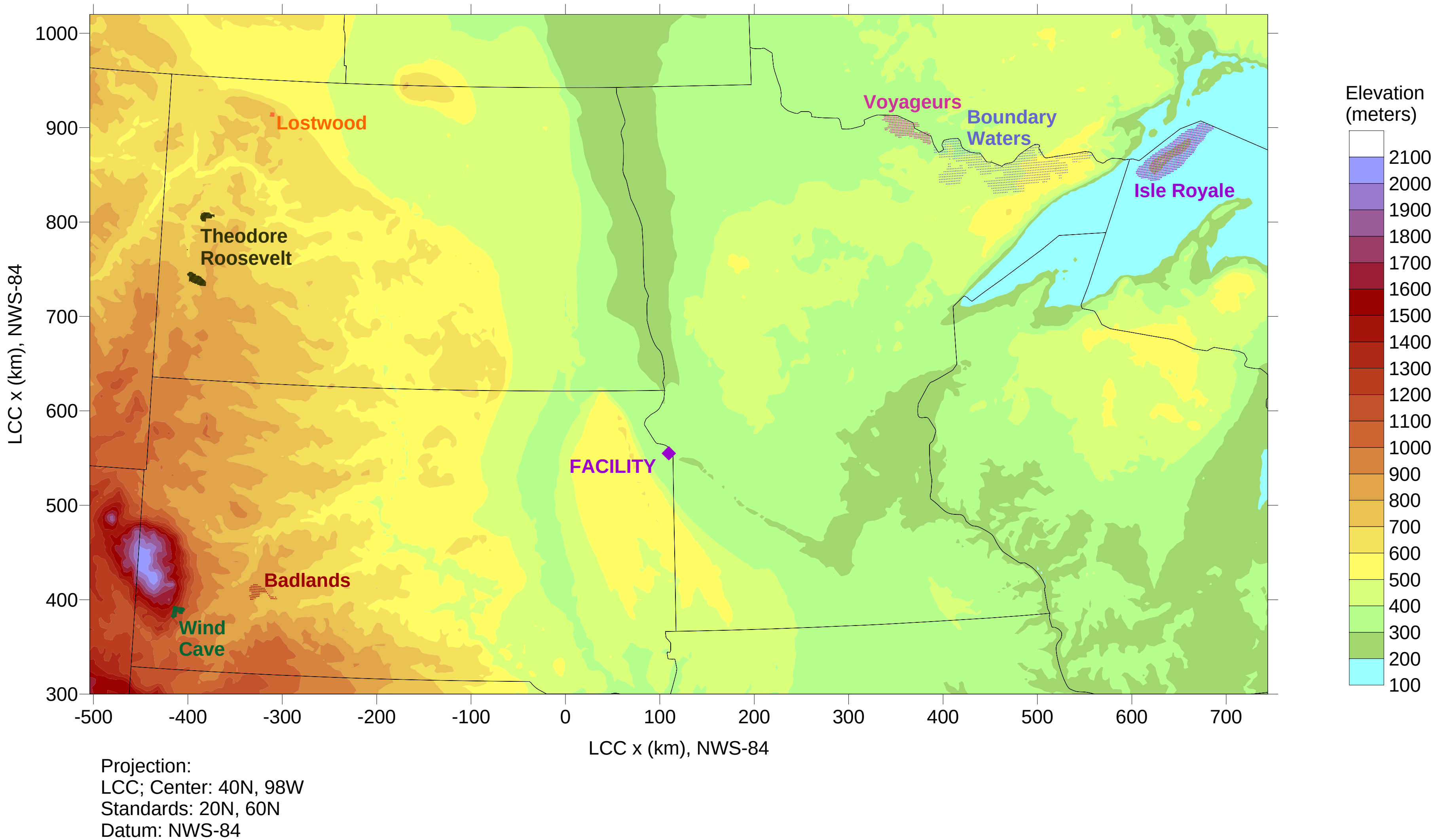

Figure 3-1. Terrain elevations for the CALMET and CALPUFF modeling domain at 4 km resolution. The locations of the Big Stone facility and Class I areas are also shown.

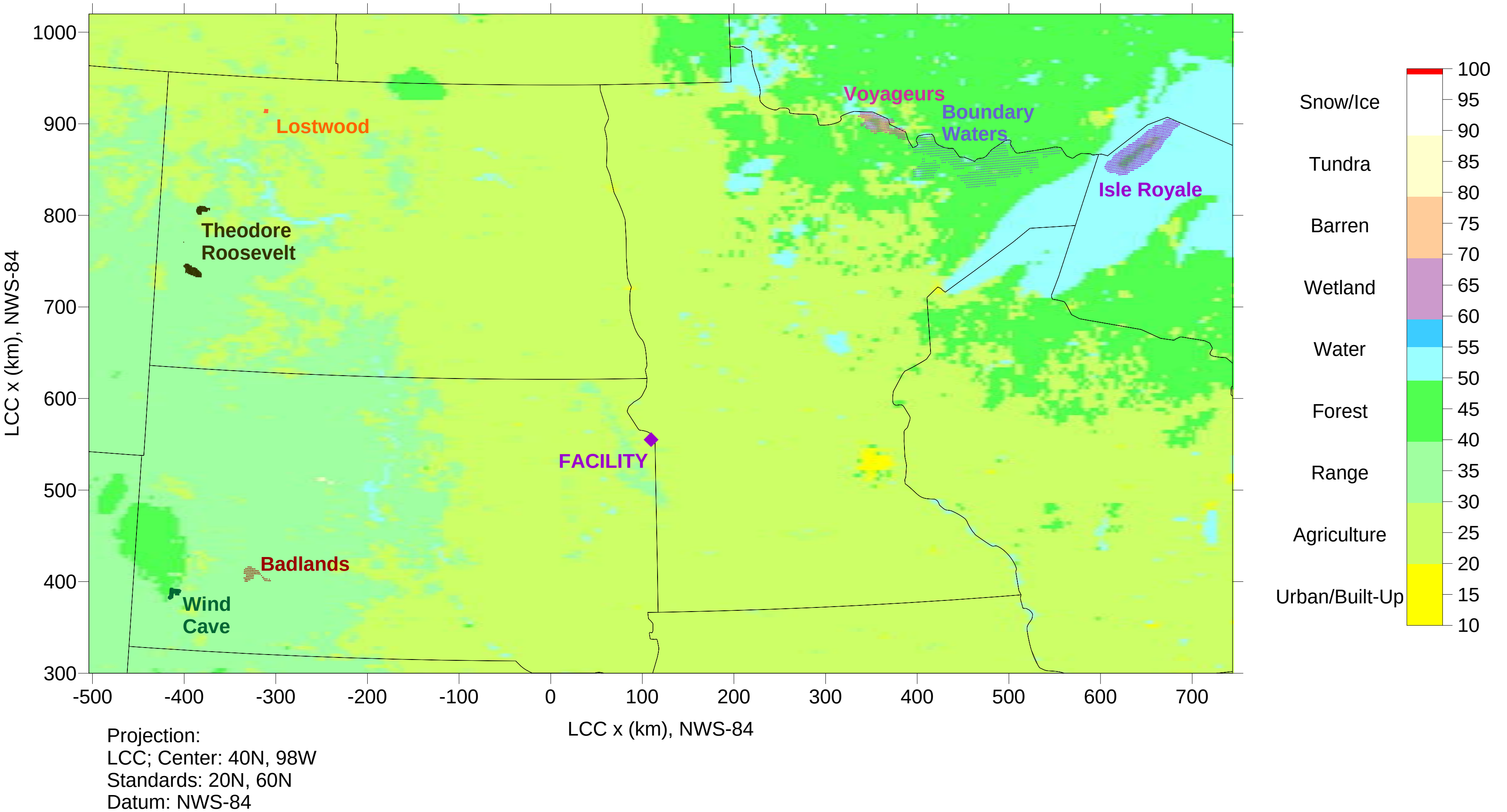

Figure 3-2. Dominant land use categories at 4 km resolution on the CALMET and CALPUFF modeling domains. The locations of the Big Stone facility and Class I areas are also shown.

Table 3-1: U.S. Geological Survey Land Use and Land Cover Classification System

	Level I		Level II
10	Urban or Built-up Land	11	Residential
		12	Commercial and Services
		13	Industrial
		14	Transportation, Communications and Utilities
		15	Industrial and Commercial Complexes
		16	Mixed Urban or Built-up Land
		17	Other Urban or Built-up Land
20	Agricultural Land	21	Cropland and Pasture
		22	Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
		23	Confined Feeding Operations
		24	Other Agricultural Land
30	Rangeland	31	Herbaceous Rangeland
		32	Shrub and Brush Rangeland
		33	Mixed Rangeland
40	Forest Land	41	Deciduous Forest Land
		42	Evergreen Forest Land
		43	Mixed Forest Land
50	Water	51	Streams and Canals
		52	Lakes
		53	Reservoirs
		54	Bays and Estuaries
		55	Oceans and Seas
60	Wetland	61	Forested Wetland
		62	Non-Forested Wetland
70	Barren Land	71	Dry Salt Flats
		72	Beaches
		73	Sandy Areas Other than Beaches
		74	Bare Exposed Rock
		75	Strip Mines, Quarries, and Gravel Pits
		76	Transitional Areas
		77	Mixed Barren Land
80	Tundra	81	Shrub and Brush Tundra
		82	Herbaceous Tundra
		83	Bare Ground
		84	Wet Tundra
		85	Mixed Tundra
90	Perennial Snow or Ice	91	Perennial Snowfields
		92	Glaciers

Table 3-2. Default CALMET Land Use Categories and Associated Geophysical Parameters based on the U.S. Geological Survey Land Use Classification System (14-Category System)

Land Use Type	Description	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux Parameter	Anthropogenic Heat Flux (W/m^2)	Leaf Area Index
10	Urban or Built-up Land	1.0	0.18	1.5	.25	0.0	0.2
20	Agricultural Land - Unirrigated	0.25	0.15	1.0	.15	0.0	3.0
-20*	Agricultural Land - Irrigated	0.25	0.15	0.5	.15	0.0	3.0
30	Rangeland	0.05	0.25	1.0	.15	0.0	0.5
40	Forest Land	1.0	0.10	1.0	.15	0.0	7.0
50	Water	0.001	0.10	0.0	1.0	0.0	0.0
54	Small Water Body	0.001	0.10	0.0	1.0	0.0	0.0
55	Large Water Body	0.001	0.10	0.0	1.0	0.0	0.0
60	Wetland	1.0	0.10	0.5	.25	0.0	2.0
61	Forested Wetland	1.0	0.1	0.5	0.25	0.0	2.0
62	Nonforested Wetland	0.2	0.1	0.1	0.25	0.0	1.0
70	Barren Land	0.05	0.30	1.0	.15	0.0	0.05
80	Tundra	.20	0.30	0.5	.15	0.0	0.0
90	Perennial Snow or Ice	.05	0.70	0.5	.15	0.0	0.0

* Negative values indicate "irrigated" land use

Table 3-3. Meteorological Data Sources and Parameters Available

Type of Dataset	Frequency	Source	Parameters available
Surface Observations	Hourly	NWS	Wind speed, wind direction, temperature, ceiling height, cloud cover, relative humidity, surface pressure, precipitation type
Upper Air	Twice-daily	NWS/NCDC	Soundings of wind speed, wind direction, temperature, and pressure
Precipitation Observations	Hourly	NWS	Precipitation rate
Buoy	Hourly	NWS/NCDC	Air-sea surface temperature difference, air temperature, relative humidity, overwater mixing height, temperature lapse rate below the mixing height overwater, temperature lapse rate above the mixing height overwater, wind speed, wind direction, dominant wave period, significant wave height
Modeled Profiles MM5 for 2002, 2006 and 2007	Hourly	EPA – 2002 TRC - 2006, 2007	Hourly, gridded fields of winds, temperature, pressure, and humidity and liquid water content on 12-km grid.

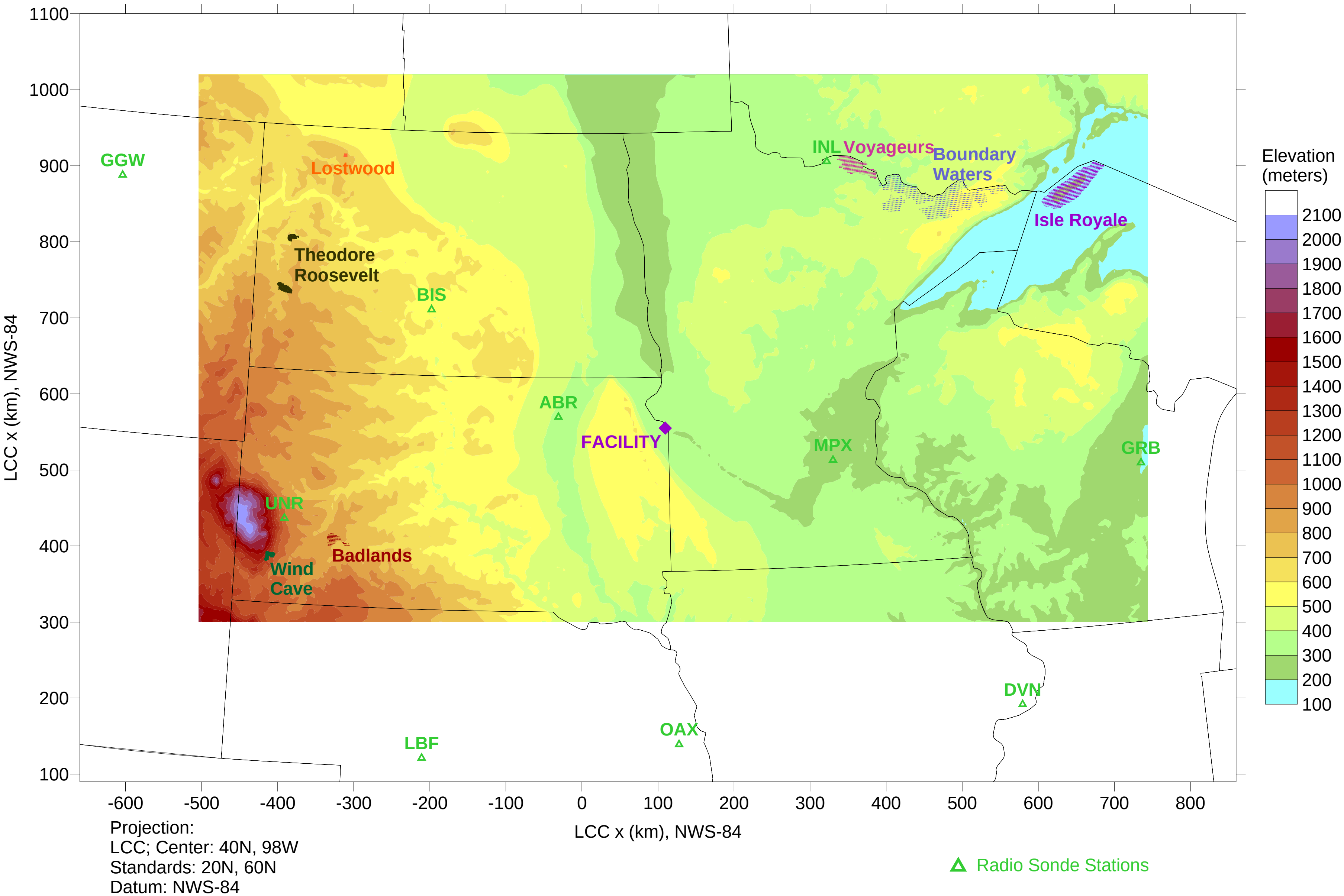

Figure 3-3. Plot of upper air stations available in the modeling domain.

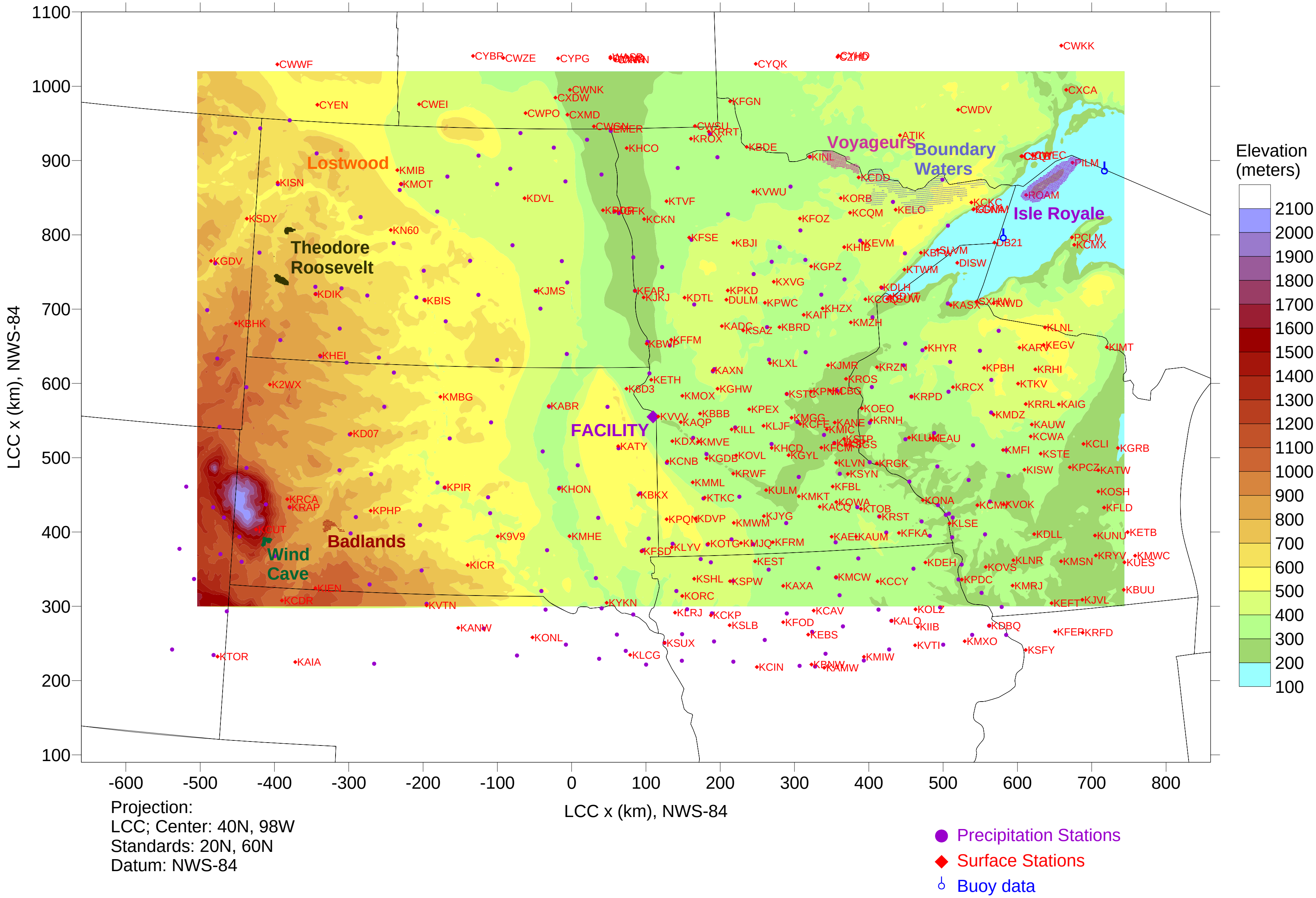

Figure 3-4. Plot of surface and precipitation stations available in the modeling domain.

3.4 Air Quality Monitoring Data

CALPUFF used hourly ozone concentration measurements in the chemical transformation rates (SO_2 to SO_4, NO_x to HNO_3/NO_3). The ambient ozone measurements are used in determining SO_2 loss rates due to chemical transformation to sulfate and in determining NO_x loss rates to nitrate. Ambient ozone hourly concentrations from EPA AIRS and CASTNet networks for 2002, 2006 and 2007 were processed into OZONE.DAT files and used as ozone background in CALPUFF. An 80 parts per billion (ppb) concentration was used as backup when hourly ozone concentrations are missing, which given the number of ozone stations was unlikely to be used.

A constant background ammonia concentration of 1 parts per billion (ppb) as recommended by the FLMs and EPA was used in the CALPUFF runs. No additional repartitioning was done on the nitrate concentrations in the base simulations (MNITRATE=0). This may produce some double-counting of ammonia in the calculation of nitrate, but any differences are likely to be small.

Additional postprocessing was conducted using POSTUTIL for an alternative case based on the full ammonia limiting method (MNITRATE=3) using background monthly average sulfate, total nitrate and total ammonia data from the 2002 CMAQ model. This option accounts for both overlapping puffs from the modeled source as well as spatial and monthly variability of ammonia and background sulfate and nitrate from sources not included in the CALPUFF simulations. The results from these simulations are also presented in Section 5.

4. AIR QUALITY MODELING OPTIONS

4.1 Modeling Domain

CALMET and CALPUFF use terrain-following coordinates. In order to cover a large enough area for the refined analysis covering all seven Class I areas within a single domain, and including a buffer of at least 50 km around each Class I area, the domain dimensions of 1250 km x 720 km were used. For a 4-km grid spacing, this amounts to 313 x 181 grid cells. In the vertical, a stretched grid was used with finer resolution in the lower layers and somewhat coarser resolution aloft thus allowing adequate representation of the mixed layer. The ten vertical levels were centered at: 10, 30, 60, 120, 240, 480, 920, 1600, 2500 and 3500 meters.

CALMET and CALPUFF were run for three years, 2002, 2006 and 2007. A network of discrete receptors derived from the list of receptors developed by the National Park Service (NPS) are located within the boundaries of the seven Class I areas modeled: Boundary Waters Canoe Area Wilderness, Voyageurs National Park, Badlands National Park, Wind Cave National Park, Lostwood National Wildlife Refuge, Theodore Roosevelt National Park and Isle Royale National Park.

4.2 Meteorological Modeling Options

4-km Simulation. EPA-approved Version 5.8 Level 070623 of CALMET was run using the recommended switch settings from U.S. EPA (2009). This includes using the regulatory set of options, including Maul-Carson convective mixing height over land only (IMIXH= - 1), OCD delta-T method for overwater fluxes (ICOARE=0), and no convective heat flux threshold overland (THRESHL= 0 W/m^3). These values of IMIXH, ICOARE and THRESHL, differ from the settings in the CALMET input files provided for sources located in South Dakota state on the WRAP Regional Modeling Center web page http://pah.cert.ucr.edu/aqm/308/bart.shtml, but follow regulatory guidance set by EPA. In addition, NOOBS was set to 0 in this application rather than 1 as in the WRAP CALMET inputs.

Initial Guess Field

MM5 data were used to define the initial guess field for the CALMET simulations (IPROG=14). For all three years hourly MM5 data with a grid spacing of 12 km were used in the modeling. The CALMET horizontal grid spacing was set to 4 km.

CALMET runs were conducted using the traditional model options including diagnostic adjustments for terrain effects, with the typical 2:1 ratio of RMAX1/R1 and RMAX2/R2. In these simulations RMAX1=100 km, RMAX2=200 km, R1=50 km and R2=100 km were used. This is consistent with the U.S. EPA (2009) recommendations. NOOBS=0 was used in the 4-km simulations. Precipitation rates were determined based on precipitation station measurements. Cloud amount and ceiling height were derived from the surface station measurements. Overwater air-sea temperature difference were derived from the buoy data (ITWPROG=0). Three-dimensional temperature fields were determined from surface and upper air observations (ITPROG=0).

Step 1 Field: Terrain Effects

In developing the Step 1 wind field, CALMET adjusts the initial guess field to terrain effects, including slope flows and blocking effects. Slope flows are a function of the local slope and altitude of the nearest crest. The crest is defined as the highest peak within a radius TERRAD around each grid point. A value of TERRAD of 15 km was used in the CALMET simulations as it is recommended by the U.S. EPA (2009) and in agreement with an analysis of the scale of the terrain. The Step 1 field produces a flow field consistent with the fine-scale CALMET terrain resolution (4 km).

Step 2 Field: Objective Analysis

In Step 2, observations are incorporated into the Step 1 wind field to produce a final wind field. Each observation site influences the final wind field within a radius of influence (parameters RMAX1 at the surface, RMAX2 aloft and RMAX3 over water). Observations and Step 1 wind fields are weighted by means of parameters R1 at the surface and R2 aloft: at a distance R1 from an observation site, the Step 1 wind field and the surface observations are weighted equally. As noted above, RMAX1/R1 and RMAX2/R2 are set with 2:1 ratio. Vertical extrapolation for the surface meteorological stations was activated (IEXTRP=-4), which is in agreement with the U.S. EPA (2009) recommendations. This setting insures that the surface observations, vertically extrapolated within the boundary layer, are blended with the MM5-based Step 1 field aloft.

4.2 Dispersion Modeling Options

CALPUFF simulations was conducted generally following the WRAP Protocol 2006 guidance, but with the EPA-approved Version 5.8 Level 070623 rather than Version 6 of the model. List of options used in the modeling includes:

- Gaussian near-field vertical distribution
- Partial plume path adjustment method for terrain
- Transitional plume rise modeled
- Partial plume penetration of elevated inversion option activated
- Stack tip downwash
- MESOPUFF II scheme for the chemical transformation
- Pasquill-Gifford (PG) dispersion coefficients (rural areas) and McElroy-Pooler coefficients (urban areas) used to compute dispersion coefficients. The probability density function (PDF) for convective conditions not used because this is available only with the turbulence-based dispersion option.
- Transition of σ_y to time-dependent (Heffter) growth rates set to 550 meters
- The switch for using Heffter equation for sigma z not activated
- PG sigma-y, z adjustment for roughness not selected
- Puff splitting (MSPLIT=1) activated
- Wet deposition, dry deposition applied
- The minimum turbulence velocities sigma-v for each stability class set to 0.5 m/s over land and 0.37 m/s over water.

The CALPUFF computational grid is the same as the meteorological grid. The modeling domain includes a buffer zone of 50 km around the source area and beyond the borders of the Class I areas. This minimizes edge effects and allows pollutants involved in flow reversals to be brought back into the Class I areas. Note that the CALMET modeling domain from previous studies was extended to include the Isle Royale National Park.

Two important computational parameters in CALPUFF are XMXLEN (maximum length of an emitted puff, in grid units) and XSAMLEN (maximum travel distance of a puff, in grid units, during one time step). Both of these variables were set to 1.0 in the CALPUFF simulations in order to allow the strong wind channeling effects to be accounted for in the puff trajectory calculations. The first parameter ensures that the length of an emitted puff does not become so large so that it cannot respond to changes in the wind field on the scale of the meteorological grid. The model automatically increases the frequency of puff releases to ensure the length of a single puff is not larger than the grid size. The second parameter decreases the internal time step to ensure the travel distance during one time step does not exceed the grid size.

The partial plume path adjustment option was used in CALPUFF for this analysis (MCTADJ=3). The CALMET wind field incorporates the effect of the terrain on the plume trajectories. The plume path coefficient was used to characterize the local effect on ground-level concentrations. The default plume path coefficients (PPC) was used for this analysis as listed below:

Stability Class	A	B	C	D	E	F
PPC	0.5	0.5	0.5	0.5	0.35	0.35

Deposition and chemical transformation effects were modeled using the default dry deposition model, the scavenging coefficient wet removal module, and the default chemical transformation mechanism.

A total of five chemically active species were modeled with CALPUFF for this analysis: SO_2, SO_4, NO_x, HNO_3 and NO_3., The chemical mechanism computes transformation rates of SO_2 to SO_4 and NO_x to NO_3/HNO_3. Hourly measured ozone concentrations were provided in an external file for use with the chemical transformation module. These ozone concentrations, along with radiation intensity, are used as surrogates for the OH concentration during the day when the gas phase free radical chemistry is active.

Six additional PM_{10} species were modeled corresponding to the midpoint of each particle size bin shown in Table 2-2. The fine, coarse, elemental carbon and organic carbon species were constructed in postprocessing steps using the POSTUTIL program from these six PM species according to the appropriate size weights for size bin as discussed in Section 2.

4.3 Visibility Calculations

Calculations of the impact of the simulated plume particulate matter component concentrations on light extinction were carried out with the CALPOST postprocessor following the new proposed FLAG (2008) guidance. The original IMPROVE/EPA equation (1) described below was recommended to determine the change in light extinction due to changes in component concentrations. Using the notations of CALPOST:

$$B_{ext} = 3f(RH)[(NH_4)2SO_4] + 3f(RH)[NH_4NO_3] + 4[OC] + 1[Soil] + 0.6[Coarse\ Mass] + 10[EC] + b_{ray} \quad (1)$$

The concentrations, in square brackets, are in µg/m³ and b_{ext} is in units of Mm^{-1}.

But a revised new IMPROVE algorithm to compute the extinction (1/Mm) has been developed by the IMPROVE steering committee for estimating light extinction from particulate matter as described in equation (2) below. This algorithm provides a better correspondence between the measured visibility and that calculated from particulate matter component concentrations (Tombach, 2006):

$$\begin{aligned} b_{ext} = & 2.2 f_S(RH) \bullet [small\ sulfate] + 4.8 f_L(RH) \bullet [large\ sulfate] \\ & + 2.4 f_S(RH) \bullet [small\ nitrate] + 5.1 f_L(RH) \bullet [large\ nitrate] \\ & + 2.8 \bullet [small\ organics] + 6.1 \bullet [large\ organics] \\ & + 10 \bullet [elemental\ carbon] \\ & + 1 \bullet [fine\ soil] \\ & + 1.7 f_{SS}(RH) \bullet [sea\ salt] \\ & + 0.6 \bullet [coarse\ matter] \\ & + Rayleigh\ scattering\ (site - specific) \\ & + 0.17 \bullet [NO_2] \end{aligned} \quad (2)$$

All of the brackets [] denote concentrations in µg/m³.

In CALPOST, the new IMPROVE algorithm as proposed by FLAG (2008) is implemented as CALPOST Method 8. The implementation of this method in CALPOST is described in more details in Appendix A. The proposed FLAG (2008) methodology is included in CALPOST V6.221 Level 080724, which has been reviewed and approved by the FLMs. This version of CALPOST is publicly available on the TRC's CALPUFF website (http://www.src.com/calpuff/calpuff1.htm) and was used for this analysis.

The Rayleigh scattering term (b_{ray}) is site-specific and computed as a function of the elevation as shown in Table 4-1, following FLAG (2008) guidance. Note that organic carbon (OC), which consists of condensable particulates and elemental carbon (EC) for soot particulates were modeled along with fine and coarse particulate matter as described in Section 2.

To represent background natural conditions, monthly background concentrations must be entered into the CALPOST input control file for all aerosols defining the background. The WRAP Protocol (2006) recommendations for natural conditions background are to use all three types of EPA default Natural Conditions: Best 20% Days, Annual Average and Worst 20% Days. In "Guidance for Estimating Visibility Conditions Under the Regional Haze Rule" (EPA, 2003), these three default values are defined only by their extinction coefficient in Mm^{-1}. For CALPOST Method 8, explicit background concentrations are required to allow the computation of the small and large sulfate particulates, nitrate particulates and organic carbon. So, in this analysis, the annual averaged background conditions were used to define the natural background for each of the seven Class I areas, following FLAG (2008). The concentrations used as background for each of the seven Class I areas are summarized in Table 4-2.

These concentrations were used to compute the natural background light extinction following the revised IMPROVE formulae described above, for each of the Class I areas.

Tables 4-3, 4-4, and 4-5, provide the monthly f(RH) values for each of the seven Class I areas, that are used to compute extinction coefficients for hygroscopic species, respectively for small ammonium sulfate and ammonium nitrate particles, large ammonium sulfate and ammonium nitrate particles, and sea salt particles.

The 8^{th} highest (98^{th} percentile) predicted light extinction change for each year modeled was compared to the threshold value of 0.5 deciview.

Table 4-1. Rayleigh Scattering Term (Mm^{-1}) for each Class I area as a Function of Elevation

Class I Area	Highest Elevation in feet (meters)	Rayleigh Scattering Term (Mm^{-1})
Boundary Waters Canoe Area Wilderness	1998.0 (609)	11
Voyageurs NP	1335.3 (407)	12
Badlands NP	3031.5 (924)	11
Wind Cave NP	4796.6 (1462)	10
Lostwood NWR	2427.8 (740)	11
Theodore Roosevelt NP	2900.3 (884)	11
Isle Royale NP	1325.5 (404)	11

Source: FLAG (2008)

Table 4-2. Annual Averaged Conditions Levels of Aerosol Components (μg/m^3) to Define Natural Background (FLAG 2008) – Method 8 values per Class I Area

Class I Area	SO_4	NO_3	OC	EC	Soil	Coarse Mass
Boundary Waters Canoe Area Wilderness	0.23	0.10	1.71	0.02	0.31	2.53
Voyageurs NP	0.23	0.10	1.75	0.02	0.26	2.73
Badlands NP	0.12	0.10	0.60	0.02	0.50	3.00
Wind Cave NP	0.12	0.10	0.60	0.02	0.49	2.98
Lostwood NWR	0.12	0.10	0.60	0.02	0.50	3.00
Theodore Roosevelt NP	0.12	0.10	0.60	0.02	0.50	3.00
Isle Royale NP	0.23	0.10	1.55	0.02	0.24	2.89

Source: FLAG (2008)

Table 4-3. Monthly Site-Specific RH adjustment factors f(RH) values for hygroscopic species – Small ammonium sulfate and ammonium nitrate particles - Method 8 (FLAG, 2008)

Class I area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Boundary Waters CAW	3.23	2.81	2.93	2.63	2.89	3.22	3.44	3.71	3.83	3.08	3.49	3.49
Voyageurs NP	3.16	2.77	2.82	2.59	2.65	3.28	3.25	3.48	3.66	3.02	3.37	3.32
Badlands NP	2.94	2.96	3.01	2.87	3.10	2.91	2.64	2.59	2.56	2.58	3.11	2.98
Wind Cave NP	2.81	2.81	2.86	2.82	3.06	2.81	2.50	2.46	2.44	2.52	2.97	2.83
Lostwood NWR	3.21	3.15	3.36	2.60	2.54	2.86	2.89	2.60	2.53	2.72	3.60	3.52
Theodore Roosevelt NP	3.17	3.11	3.22	2.71	2.74	2.85	2.73	2.49	2.48	2.66	3.42	3.37
Isle Royale NP	3.26	2.74	2.87	2.58	2.46	3.00	3.59	3.68	3.92	2.88	3.72	3.67

Source: FLAG (2008)

Table 4-4. Monthly Site-Specific RH adjustment factors f(RH) values for hygroscopic species – Large ammonium sulfate and ammonium nitrate particles – Method 8 (FLAG, 2008)

Class I area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Boundary Waters CAW	2.50	2.25	2.28	2.09	2.20	2.43	2.57	2.71	2.78	2.38	2.64	2.64
Voyageurs NP	2.46	2.22	2.22	2.07	2.09	2.46	2.46	2.59	2.70	2.35	2.58	2.55
Badlands NP	2.31	2.31	2.31	2.21	2.34	2.25	2.08	2.05	2.02	2.05	2.38	2.33
Wind Cave NP	2.23	2.22	2.22	2.18	2.32	2.18	2.00	1.97	1.95	2.00	2.30	2.24
Lostwood NWR	2.51	2.45	2.54	2.06	2.03	2.21	2.23	2.05	2.02	2.13	2.69	2.67
Theodore Roosevelt NP	2.47	2.42	2.45	2.12	2.14	2.21	2.14	1.99	1.99	2.10	2.58	2.57
Isle Royale NP	2.53	2.21	2.26	2.07	1.99	2.32	2.65	2.69	2.82	2.28	2.76	2.74

Source: FLAG (2008)

Table 4-5. Monthly Site-Specific RH adjustment factors f(RH) values for hygroscopic species – Sea salt particles - Method 8 (FLAG, 2008)

Class I area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Boundary Waters CAW	3.73	3.35	3.29	2.91	3.00	3.44	3.68	3.88	3.98	3.45	3.89	3.91
Voyageurs NP	3.69	3.31	3.20	2.90	2.89	3.46	3.55	3.71	3.87	3.42	3.83	3.80
Badlands NP	3.37	3.33	3.27	3.05	3.25	3.15	2.89	2.81	2.74	2.82	3.41	3.38
Wind Cave NP	3.25	3.20	3.13	3.01	3.22	3.06	2.75	2.68	2.63	2.75	3.28	3.24
Lostwood NWR	3.77	3.66	3.67	2.86	2.79	3.07	3.11	2.82	2.80	2.99	3.93	3.95
Theodore Roosevelt NP	3.67	3.56	3.51	2.93	2.97	3.09	2.96	2.72	2.72	2.93	3.75	3.78
Isle Royale NP	3.78	3.34	3.28	2.93	2.78	3.31	3.83	3.87	4.06	3.40	4.05	4.04

Source: FLAG (2008)

5. RESULTS

The results for the BART analysis for the Big Stone I facility are presented in this section. The analysis consists of evaluating the visibility impact (percent change in light extinction due to the sources measured in deciview) at all the Class I areas modeled. The results for the base case are presented in three tables, each table gathering the impact at seven Class I areas for each of the years modeled: Table 5-1 for 2002, Table 5-2 for 2006 and Table 5-3 for 2007. The change in light extinction due to the source is compared to the annual average natural background light extinction. The interpretation of the results is done by comparing the 98th percentile of Delta deciview for each year to the 0.5 delta deciview threshold. Analysis is performed by using CALPOST Method 8.

Ammonia Limiting Method (ALM) with CMAQ 2002 monthly averages as background was performed as well. These results are presented in Tables 5-4 through 5-6.

Table 5-1. Visibility impacts for 2002. Constant (1 ppb) ammonia.

Park	Max Delta Deciview	4th Highest (99%)	8th Highest (98%)	Nb. Exceed. > 5%	Nb. Exceed. > 10%
Boundary Waters	1.315	0.837	**0.574**	14	1
Voyageurs	2.162	0.690	**0.623**	9	3
Wind Cave	0.873	0.475	0.305	3	0
Theodore Roosevelt	1.390	0.555	0.215	4	1
Lostwood National	0.564	0.388	0.232	2	0
Badlands	0.762	0.671	0.452	7	0
Isle Royale	1.182	0.789	**0.629**	10	2

Table 5-2. Visibility impacts for 2006. Constant (1 ppb) ammonia.

Park	Max Delta Deciview	4th Highest (99%)	8th Highest (98%)	Nb. Exceed. > 5%	Nb. Exceed. > 10%
Boundary Waters	2.572	1.183	**0.790**	16	5
Voyageurs	1.578	0.862	**0.574**	11	2
Wind Cave	0.454	0.302	0.120	0	0
Theodore Roosevelt	2.232	0.772	0.459	6	3
Lostwood National	1.110	0.662	0.385	5	1
Badlands	1.002	0.519	0.481	7	1
Isle Royale	1.806	0.635	**0.506**	8	2

Table 5-3. Visibility impacts for 2007. Constant (1 ppb) ammonia.

Park	Max Delta Deciview	4th Highest (99%)	8th Highest (98%)	Nb. Exceed. > 5%	Nb. Exceed. > 10%
Boundary Waters	3.574	1.351	**1.079**	25	9
Voyageurs	2.062	1.376	**0.724**	19	5
Wind Cave	1.671	0.591	0.325	4	2
Theodore Roosevelt	0.744	0.491	0.322	3	0
Lostwood National	0.959	0.722	0.409	6	0
Badlands	2.202	0.698	0.471	6	2
Isle Royale	1.224	0.745	**0.665**	13	2

Table 5-4. Visibility impacts with ALM considered for 2002.

Park	Max Delta Deciview	4th Highest (99%)	8th Highest (98%)	Nb. Exceed. > 5%	Nb. Exceed. > 10%
Boundary Waters	0.740	0.491	0.389	3	0
Voyageurs	1.256	0.546	0.380	4	1
Wind Cave	0.725	0.435	0.275	3	0
Theodore Roosevelt	1.355	0.472	0.181	2	1
Lostwood National	0.510	0.298	0.198	1	0
Badlands	0.714	0.617	0.422	7	0
Isle Royale	0.661	0.560	0.350	4	0

Table 5-5. Visibility impacts with ALM considered for 2006.

Park	Max Delta Deciview	4th Highest (99%)	8th Highest (98%)	Nb. Exceed. > 5%	Nb. Exceed. > 10%
Boundary Waters	1.439	0.830	**0.550**	10	3
Voyageurs	1.150	0.540	0.391	5	1
Wind Cave	0.319	0.191	0.111	0	0
Theodore Roosevelt	1.280	0.606	0.367	5	1
Lostwood National	0.673	0.521	0.377	4	0
Badlands	0.917	0.477	0.269	3	0
Isle Royale	0.805	0.467	0.352	1	0

Table 5-6. Visibility impacts with ALM considered for 2007.

Park	Max Delta Deciview	4th Highest (99%)	8th Highest (98%)	Nb. Exceed. > 5%	Nb. Exceed. > 10%
Boundary Waters	1.530	0.786	**0.654**	13	2
Voyageurs	1.357	0.714	**0.553**	9	1
Wind Cave	0.713	0.427	0.276	3	0
Theodore Roosevelt	0.724	0.388	0.278	2	0
Lostwood National	0.934	0.563	0.353	4	0
Badlands	1.042	0.571	0.353	5	1
Isle Royale	0.793	0.551	0.486	7	0

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APPENDIX A

CALPOST VISIBILITY METHOD 8

The revised visibility algorithm developed for the IMPROVE Steering Committee (IMPROVE 2005) as recommended by FLAG (2008) has been implemented in CALPOST. It differs from the previous IMPROVE algorithm as used in Method 2 and Method 6 in six areas:

- Extinction efficiencies of sulfates, nitrates, and organics vary with concentration, as there are distinct efficiencies for "small" and "large" particles and the ratio of small-to-large particle fraction decreases as the concentration increases. Furthermore, the extinction efficiency for sulfates no longer equals that for nitrates.
- A separate hygroscopic humidity enhancement factor curve is prescribed for "small" and "large" particles, $f_S(RH)$ and $f_L(RH)$. These curves apply to sulfates and nitrates.
- Light extinction due to scattering by sea salt (with its own hygroscopic humidity enhancement factor $f_{SS}(RH)$) is included.
- Light absorption by NO_2 gas is included in the extinction.
- Background particulate organic matter concentration is taken to be 1.8 times measured organic carbon concentrations.
- Rayleigh scattering extinction varies with site elevation and mean temperature.

Items 5 and 6 remain direct inputs to CALPOST, and required no structural changes to the postprocessor. The user must confirm that appropriate values are provided.

Item 4, the introduction of light extinction due to NO_2 gas absorption, has been added to CALPOST as a discrete component independent of the visibility method chosen. New control file inputs associated with NO_2 in the recommended FLAG (2008) mode are:

```
Source of NO2 when ASPEC=NO2 (above) or LVNO2=T (Group 2) may be
from CALPUFF NO2 concentrations OR from a fraction of CALPUFF NOx
concentrations.  Specify the fraction of NOx that is treated as NO2
either as a constant or as a table of fractions that depend on the
magnitude of the NOx concentration:
                       (NO2CALC) -- Default: 1   ! NO2CALC =   1  !
   0 =  Use NO2 directly (NO2 must be in file)
   1 =  Specify a single NO2/NOx ratio (RNO2NOX)
   2 =  Specify a table NO2/NOx ratios (TNO2NOX)
        (NOTE: Scaling Factors must NOT be used with NO2CALC=2)

Single NO2/NOx ratio (0.0 to 1.0) for treating some
or all NOx as NO2, where [NO2] = [NOX] * RNO2NOX
(used only if NO2CALC = 1)
                       (RNO2NOX) -- Default: 1.0 ! RNO2NOX = 1.0 !
```

Items 1 through 3 are implemented as visibility Method 8 in CALPOST, along with the specific choice of the new f(RH) curves. Selection of the revised IMPROVE algorithm requires the following new control file selections:

```
Particle growth curve f(RH) for hygroscopic species
                           (MFRH) -- Default: 2   ! MFRH   = 4  !
     1 =  IWAQM (1998) f(RH) curve (originally used with MVISBK=1)
     2 =  FLAG (2000) f(RH) tabulation
     3 =  EPA (2003) f(RH) tabulation
     4 =  IMPROVE (2006) f(RH) tabulations for sea salt, and for
          small and large SULFATE and NITRATE particles;
          Used with Visibility Method 8 (MVISBK = 8)

Method used for background light extinction
                         (MVISBK) -- Default: 2   ! MVISBK =  8  !
     1 =  Supply single light extinction and hygroscopic fraction
     2 =  Compute extinction from speciated PM measurements (A)
     3 =  Compute extinction from speciated PM measurements (B)
     4 =  Read hourly transmissometer background extinction measurements
     5 =  Read hourly nephelometer background extinction measurements
     6 =  Compute extinction from speciated PM measurements
     7 =  Use observed weather or prognostic weather information for
          background extinction during weather events; otherwise, Method 2
     8 =  Compute extinction from speciated PM measurements using the
          IMPROVE (2006) variable extinction efficiency formulation
          (MFRH must be set to 4)
          - Split between small and large particle concentrations of
            SULFATES, NITRATES, and ORGANICS is a function of concentration
            and different extinction efficiencies are used for each
          - Source-induced change in visibility includes the increase in
            extinction of the background aerosol due to the change in the
            extinction efficiency that now depends on total concentration.
          - Fsmall(RH) and Flarge(RH) adjustments for small and large
            particles are applied to observed and modeled sulfate and
            nitrate concentrations
          - Fsalt(RH) adjustment for sea salt is applied to background
            sea salt concentrations
          - F(RH) factors are capped at F(RHMAX)
          - RH for Fsmall(RH), Flarge(RH), and Fsalt(RH) may be obtained
            from hourly data as in Method 2 or from the FLAG monthly RH
            adjustment factor used for Method 6 where EPA F(RH) tabulation
            is used to infer RH, or monthly Fsmall, Flarge, and Fsalt RH
            adjustment factors can be directly entered. Furthermore, a
            monthly RH factor may be applied to either hourly
            concentrations or daily concentrations to obtain the 24-hour
            extinction.

            These choices are made using the M8_MODE selection.
```

```
    Additional inputs used for MVISBK = 8:
    -------------------------------------
Extinction coefficients for hygroscopic species (modeled and
background) may be computed using hourly RH values and hourly
modeled concentrations, or using monthly RH values inferred from
the RHFAC adjustment factors and either hourly or daily modeled
concentrations, or using monthly RHFSML, RHFLRG, and RHFSEA adjustment
factors and either hourly or daily modeled concentrations.

     (M8_MODE) -- Default: 5     ! M8_MODE=  5   !
                  FLAG (2008)

          1 = Use hourly RH values from VISB.DAT file with hourly
              modeled and monthly background concentrations.
          2 = Use monthly RH from monthly RHFAC and EPA (2003) f(RH)
              tabulation with hourly modeled and monthly background
              concentrations.
                            (VISB.DAT file is NOT needed).
          3 = Use monthly RH from monthly RHFAC with EPA (2003) f(RH)
              tabulation with daily modeled and monthly background
              concentrations.
                            (VISB.DAT file is NOT needed).
          4 = Use monthly RHFSML, RHFLRG, and RHFSEA with hourly modeled and
              monthly background concentrations.
                            (VISB.DAT file is NOT needed).
          5 = Use monthly RHFSML, RHFLRG, and RHFSEA with daily modeled
              and monthly background concentrations.
                            (VISB.DAT file is NOT needed).
```

The last of these selections, M8_MODE, provides options for how concentrations are averaged, and how the relative humidity enhancement factors for hygroscopic species are determined. M8_MODE has a default value of 5, which is consistent with the new FLAG (2008) guidance

APPENDIX B

MM5 MODEL CONFIGURATION

MM5 Domain Configuration (36-km, 12-km Resolution)

The Fifth Generation Penn State University/NCAR Mesoscale Model (MM5) (Dudhia et al, 2000) has been run for 2006 and 2007 for North America for two domains: a coarse Domain 1 (36-km resolution), and a nested Domain 2 (12-km resolution). The Lambert Conical Conformal (LCC) mapping projection is used in modeling. The center of the coordinate system is located at the center of Domain 1 at 40^{o}N and 98^{o}W. Two standard latitudes of LCC are set to 20^{o}N and 60^{o}N. The coarse domain (Domain 1) covers an area of 7488 km in the west-east (X) direction by 6768 km in the south-north (Y) direction with grid spacing of 36 km (Table B-1). Figure B-1 shows Modeling Domains 1 and 2.

There are forty-one sigma levels in the vertical direction from the surface up to 100 hPa (Table B-2). The first sigma level is about 11 m above the ground, very close to the anemometer height at operational weather stations. The vertical spatial resolution varies from the surface to the model top. About twenty levels are below 1500 m above the ground for better resolving the atmospheric boundary layer in the model.

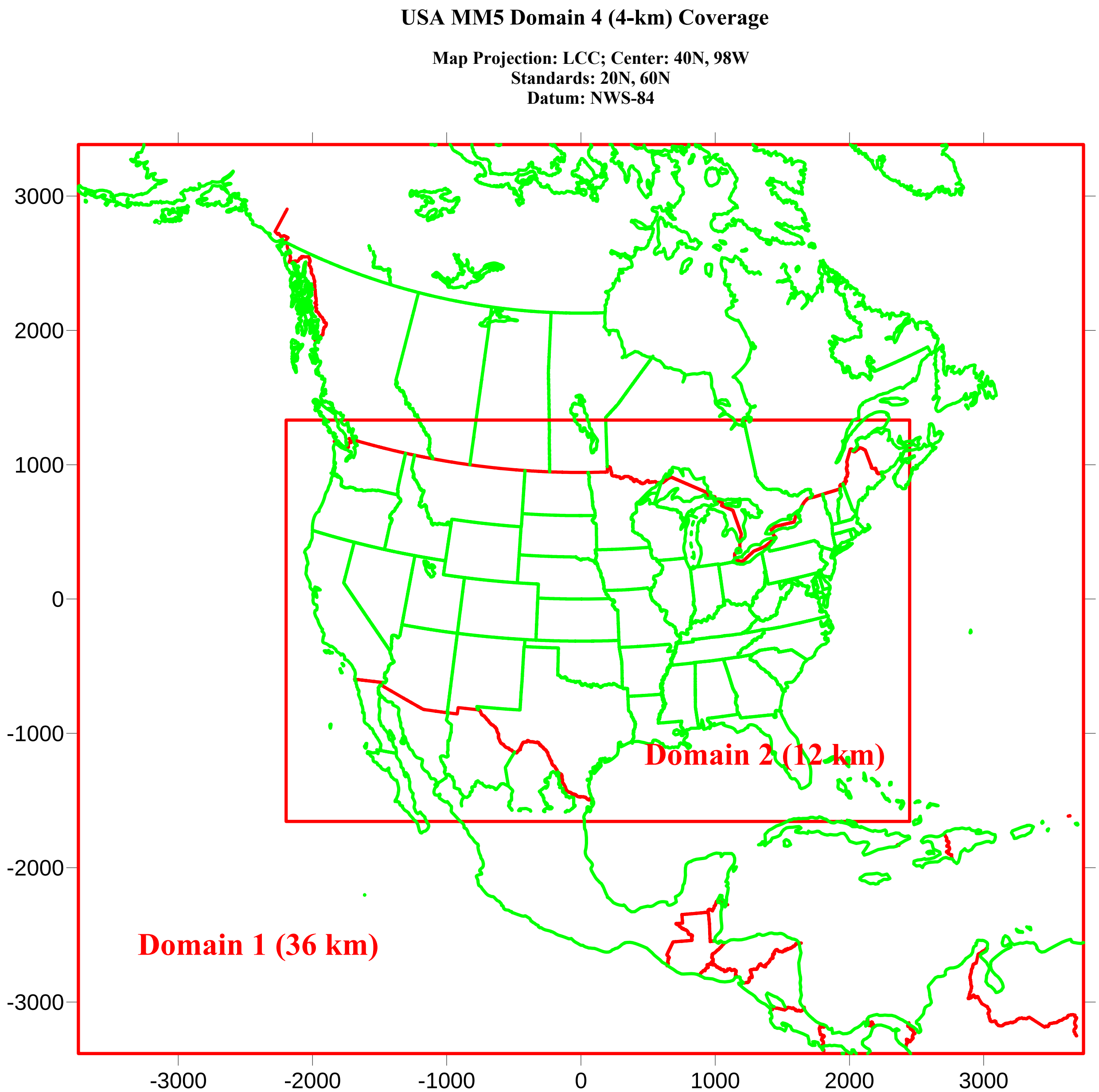
Model Parameterizations and Schemes

The MM5 model was run for 2006 and 2007 in the non-hydrostatic mode using the upper radiative boundary condition. MM5 physical schemes and parameterizations are listed in Table B-1. The Reisner graupel scheme was used for the explicit moisture parameterization. It predicts all five water contents in the atmosphere. This scheme includes additional equation to predict graupel. It is a more computationally expensive scheme compared with simple ice scheme. The cumulus scheme used in MM5 is the Kain-Fritsch 2 scheme (Kain, 2004). This scheme includes shallow convection. For planetary boundary layer (PBL) scheme, the Mellor-Yamada scheme used in the ETA model (Janjic, 1990, 1994) was used in this MM5 modeling. This scheme was implemented in the NCEP MRF model. It is efficient and suitable for high-resolution PBL. The Rapid Radiative Transfer Model was used for the radiation scheme in both Domains (Mlawer et al., 1997). This scheme is a highly accurate and efficient method developed by AER Inc. Multiple-layer soil temperatures were computed using the NOAH land surface model (National Centers for Environmental Prediction, Oregon State University, Air Force, and Hydrologic Research Laboratory). Additional geographical data, such as soil types, vegetation fraction, and annual deep soil temperatures are needed for the land surface model; and these data were obtained from NCAR.

One way nesting is used in the MM5 simulation, meaning that the mother domain is not affected by its child-domain. Such nesting allows adding new domains later without re-running all the other domains. Analysis Four Dimensional Data Assimilation (FDDA) was applied to both Domain 1 and Domain 2.

Table B-1 Domain Configuration and Parameterizations for 2006 and 2007 MM5 Simulations. The Lambert Conical Conformal (LCC) map projection is used in the MM5 modeling.

Settings	Domain 1	Domain 2
Grid number	209 x 189	388 x 250
Grid size (km)	36	12
Nesting	NA	One-way
Sigma levels	41	41
Moisture	Reisner 2	Reisner 2
Cumulus	Kain-Fritsch 2	Kain-Fritsch 2
Boundary layer	ETA	ETA
Radiation	RRTM	RRTM
Soil model	NOAH LSM	NOAH LSM
FDDA	3D and Surface Analysis	3D and Surface Analysis
Run Length	2.5 days	2.5 days
Spin-up time	12 hours	12 hours
Terrain and land-use data	USGS 10-minute (~19 km)	USGS 5-minute (~9 km)



MM5 Domains:
D1: X: -3744 - 3744 km, Y: -3384 - 3384 km; dxy= 36 km; 209 x 189 i1= 1,j1= 1
D2: X: -2196 - 2448 km, Y: -1656 - 1332 km; dxy= 12 km; 388 x 250 i1= 44,j1= 49

D3: X: -612 - 864 km, Y: -48 - 1080 km; dxy= 4 km; 370 x 283 i1=133,j1=135

Figure B-1. Map showing the MM5 Domain 1 (36-km) and Domain 2 (12-km).

Table B-2. Sigma Levels used in the North American MM5 Simulations for 2006 and 2007.

Level	Sigma	Half Sigma	Ref. Pressure (mb)	Height (m)
surface	1.0000	-	1010.0	0.0
1	0.9970	0.9985	1008.6	10.9
2	0.9936	0.9953	1005.7	34.1
3	0.9898	0.9917	1002.4	60.3
4	0.9856	0.9877	998.8	89.6
5	0.9808	0.9832	994.7	122.5
6	0.9754	0.9781	990.1	160.0
7	0.9694	0.9724	984.9	202.1
8	0.9626	0.9660	979.1	249.6
9	0.9549	0.9588	972.5	303.7
10	0.9463	0.9506	965.0	364.8
11	0.9367	0.9415	956.8	433.5
12	0.9258	0.9313	947.4	511.5
13	0.9136	0.9197	936.9	600.1
14	0.8999	0.9068	925.1	700.4
15	0.8845	0.8922	911.9	814.4
16	0.8672	0.8759	897.0	944.1
17	0.8477	0.8575	880.3	1092.1
18	0.8258	0.8368	861.4	1261.5
19	0.8012	0.8135	840.3	1455.3
20	0.7736	0.7874	816.5	1677.7
21	0.7425	0.7581	789.8	1934.1
22	0.7076	0.7251	759.8	2230.9
23	0.6683	0.6880	726.0	2576.1
24	0.6242	0.6463	688.1	2980.0
25	0.5746	0.5994	645.5	3455.7
26	0.5188	0.5467	597.5	4021.9
27	0.4688	0.4938	549.4	4628.0
28	0.4284	0.4486	508.2	5180.4
29	0.3879	0.4082	471.4	5705.6
30	0.3474	0.3677	434.6	6265.0
31	0.3065	0.3270	397.5	6866.0
32	0.2620	0.2843	358.7	7545.5
33	0.2175	0.2398	318.2	8317.4
34	0.1675	0.1925	275.2	9224.7
35	0.1175	0.1425	229.7	10311.2
36	0.0783	0.0979	189.1	11426.7
37	0.0588	0.0686	162.4	12261.6
38	0.0392	0.0490	144.6	12875.1
39	0.0196	0.0294	126.8	13547.3
40	0.0000	0.0098	108.9	14290.2

Initial Data and Simulation

MM5 is initialized using the $1^o \times 1^o$ Final Analysis (FNL) data from NCEP at NCAR. It is an improvement of the original 2.5-degree by 2.5-degree dataset. The FNL data were archived at NCAR with temporal resolution of six hours at the surface and 26 standard pressure levels under 10 hPa: 1000, 975, 950, 925, 900, 850, 800, 750, 700, 650, 600, 550, 500, 450, 400, 350, 300, 250, 200, 150, 100, 70, 50, 30, 20, and 10 hPa. The dataset includes two-dimensional variables of snow cover, sea surface temperature (SST), sea level pressure, and three-dimensional variables of temperature, geopotential height, U and V components, and relative humidity.

The SST spatial resolution of $1^o \times 1^o$ in FNL data is too coarse in the coastal area. To improve SST in MM5, a better SST dataset, the daily 4-km MODIS SSTs, is ingested into the simulation. The MODIS (MODerate Resolution Imaging Spectroradiometer) SSTs are derived from the sensors onboard the NASA Terra and Aqua platforms. The MODIS SSTs include from both the sensors of mid-infrared (IR) and thermal IR channels. The product used in the simulation is the MODIS Global Level 3 Mapped mid-IR SSTs.

MM5 is run for 2.5-day periods with 12 hours for spin-up time. The initial FNL data are model output and already in the dynamically-consistent state. The spin-up time of 12 hours is enough to allow MM5 reach dynamical balance in its domains. The 2.5-day simulation length can reduce the divergence between forecasts and analyses. MM5 output covers the period from 2005123112 to 2007010111, so that any conversion between local and UTC times can be properly processed. There are 183 2.5-day simulations in total for the annual period.

Evaluation of model performance

The MM5 model output dataset was evaluated using observations from hourly and synoptic surface data available from the US National Climatic Data Center (NCDC) in Asheville, North Carolina. The locations of the stations used in the evaluation are shown in Figure 3-4. The statistical index used for the evaluation is the Index of Agreement (IOA) is defined as:

$$IOA = 1 - \left[\frac{IJ.RMSE^2}{\sum_{j=1}^{J} \sum_{i=1}^{I} \left|P_j^i - M_o\right| + \left|O_j^i - M_o\right|} \right] \qquad (1)$$

where RMSE is the Root Mean Square Error, and calculated using the equation

$$RMSE = \left[\frac{i}{IJ} \sum_{j=1}^{J} \sum_{i=1}^{I} (P_j^i - O_j^i)^2 \right]^{1/2} \qquad (2)$$

P_j^i and O_j^i are the prediction and the observation at Station *j* and time *i*. M_o is the Mean Observations and equal to

$$M_o = \frac{1}{IJ} \sum_{j=1}^{J} \sum_{i=1}^{I} O_j^i \qquad (3)$$

The other two quantities used in the evaluation are Mean Bias Error (B) and Gross Error (E). Mean Bias Error is calculated using

$$B = \frac{1}{IJ} \sum_{j=1}^{J} \sum_{i=1}^{I} \left(P_j^i - O_j^i \right) \qquad (4)$$

Gross Error equals

$$E = \frac{1}{IJ} \sum_{j=1}^{J} \sum_{i=1}^{I} \left| P_j^i - O_j^i \right| \qquad (5)$$

In their studies, Emery et al. (2001) and Tesche et al. (2001) provided benchmarks for MM5 model evaluation or for other three-dimensional mesoscale model evaluation based on MM5/RAMS model performance evaluation literature. The benchmarks are for wind speed, wind direction, temperature and specific humidity. These benchmarks are "not to assign a passing or failing grade to a particular meteorological modeling application, but rather to put its results into a useful contact" (Tesche et al., 2002). It is not expected that all simulations will fall within the benchmarks, but rather the benchmarks are useful in comparing the results from various simulations in a quantitative manner. The benchmarks were designed to be used with large groups of stations in a given region or stations of a particular classification rather than with individual stations.

Table B-3 contains a summary of the statistical measures above comparing using hourly surface meteorological observations with the MM5 modeling results prepared by TRC for 2006 and 2007. Also included is a comparison of the results with the EPA-sponsored 2002 MM5 dataset which has been subject to previous model evaluations. The comparisons were done using the surface meteorological stations within the CALPUFF modeling domain, which consisted of 172, 210 and 210 stations for 2002, 2006 and 2007, respectively. The performance is similar for each of the datasets. The statistical measures are all better than the benchmark values, with the exception in the 2002 dataset of the mean gross error for temperature, which is slight above the benchmark, and the Index of Agreement (IOA), which is slightly lower than the benchmark.

Table B-3. Performance Statistics by Year – MM5 Simulations – 12-km Grid Resolution

	Wind Speed			Wind Direction		Temperature			Specific Humidity		
	Mean IOA	Mean Bias	Mean RMSE	Mean Bias	Mean Gross Error	Mean IOA	Mean Bias	Mean Gross Error	Mean IOA	Mean Bias	Mean Gross Error
2002	0.77	0.18	1.88	2.70	21.15	0.79	-0.05	2.75	0.84	-0.06	0.73
2006	0.83	0.04	1.54	1.76	16.68	0.96	-0.19	1.19	0.81	0.43	0.83
2007	0.83	0.14	1.59	2.31	17.05	0.96	-0.12	1.23	0.81	0.47	0.86
Benchmark	**x ≥ 0.60**	**|x| ≤ 0.50**	**x ≤ 2.00**	**|x| ≤ 10.0**	x ≤ **30.0**	**x ≥ 0.80**	**|x| ≤ 0.50**	**x ≤ 2.00**	**x ≥ 0.60**	**|x| ≤ 1.00**	**x ≤ 2.00**

References for Appendix B

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Tesche, T.W., D.E. McNally and C. Tremback, 2002: Operational evaluation of the MM5 model over the Continental United States: Protocol for annual and episodic evaluation. Prepared for the Office of Air Quality Planning and Standards, U.S. EPA, Research Triangle Park, NC.

APPENDIX C

CALMET CONTROL FILE WITH MODEL SETTINGS

```
4 km resolution CALMET simulation
BART Analysis
Otter Tail Power Big Stone I 2006
---------------- 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-4km-hires.dat !
SURF.DAT      input    ! SRFDAT=bs_surf2006ext.dat       !
CLOUD.DAT     input    * CLDDAT=            *
PRECIP.DAT    input    ! PRCDAT=bs_precip-2006ext.dat    !
WT.DAT        input    * WTDAT=             *

CALMET.LST    output   ! METLST=met2006_4km_a2r2_011.lst !
CALMET.DAT    output   ! METDAT=met2006_4km_a2r2_011.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 =  10  !
    Number of overwater met stations
                                 (NOWSTA) No default     ! NOWSTA =  2  !

NUMBER OF PROGNOSTIC and IGF-CALMET FILEs:

    Number of MM4/MM5/3D.DAT files
                                 (NM3D) No default       ! NM3D = 1  !

    Number of IGF-CALMET.DAT files
                                 (NIGF)   No default     ! NIGF =  0  !

                       !END!
--------------------------------------------------------------------------------
Subgroup (b)
---------------------------------
Upper air files (one per station)
---------------------------------
Default Name  Type       File Name
------------  ----       ---------
UP1.DAT       input     1  ! UPDAT= up-abr-2006n.dat!    !END!
UP2.DAT       input     2  ! UPDAT= up-bis-2006n.dat!    !END!
UP3.DAT       input     3  ! UPDAT= up-dvn-2006n.dat!    !END!
UP4.DAT       input     4  ! UPDAT= up-ggw-2006n.dat!    !END!
UP5.DAT       input     5  ! UPDAT= up-grb-2006n.dat!    !END!
UP6.DAT       input     6  ! UPDAT= up-inl-2006n.dat!    !END!
UP7.DAT       input     7  ! UPDAT= up-lbf-2006n.dat!    !END!
UP8.DAT       input     8  ! UPDAT= up-mrx-2006n.dat!    !END!
UP9.DAT       input     9  ! UPDAT= up-oax-2006n.dat!    !END!
UP0.DAT       input    10  ! UPDAT= up-unr-2006n.dat!    !END!

--------------------------------------------------------------------------------
Subgroup (c)
-----------------------------------------
Overwater station files (one per station)
-----------------------------------------
Default Name  Type       File Name
------------  ----       ---------
SEA1.DAT      input     1  ! SEADAT= 45001-2006.dat!    !END!
SEA2.DAT      input     2  ! SEADAT= 45006-2006.dat!    !END!
```

```
--------------------------------------------------------------------------------
Subgroup (d)
------------------------------------------------
MM4/MM5/3D.DAT files (consecutive or overlapping)
------------------------------------------------
Default Name  Type       File Name
------------  ----       ---------

MM5001 ! M3DDAT=../mm5_2006/mm5-200601.m3d! !END!
--------------------------------------------------------------------------------
Subgroup (e)
-------------------------------------------------
IGF-CALMET.DAT files (consecutive or overlapping)
-------------------------------------------------
Default Name  Type       File Name
------------  ----       ---------
IGFn.DAT       input     1  * IGFDAT=CALMET0.DAT *    *END*
--------------------------------------------------------------------------------
Subgroup (f)
----------------
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=                  *
DCST.GRD      output     * DCSTGD=                  *

--------------------------------------------------------------------------------
NOTES: (1) File/path names can be up to 70 characters in length
       (2) Subgroups (a) and (f) must have ONE 'END' (surrounded by
           delimiters) at the end of the group
       (3) Subgroups (b) through (e) are included ONLY if the corresponding
           number of files (NUSTA, NOWSTA, NM3D, NIGF) is not 0, and each 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=  2006  !
                     Month (IBMO) -- No default       ! IBMO=  1  !
                       Day (IBDY) -- No default       ! IBDY=  1  !
                      Hour (IBHR) -- No default       ! IBHR=  1  !

     Note: IBHR is the time at the END of the first hour of the simulation
           (IBHR=1, the first hour of a day, runs from 00:00 to 01:00)

     Base time zone        (IBTZ) -- No default       ! IBTZ=  7  !
        PST = 08, MST = 07
        CST = 06, EST = 05

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

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

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

     Compute special data fields required
```

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

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


     Test options specified to see if
     they conform to regulatory
     values? (MREG)                   No Default       ! MREG =  1   !

        0 = NO checks are made
        1 = Technical options must conform to USEPA guidance
                  IMIXH    -1       Maul-Carson convective mixing height
                                    over land; OCD mixing height overwater
                  ICOARE   0        OCD deltaT method for overwater fluxes
                  THRESHL  0.0      Threshold buoyancy flux over land needed
                                    to sustain convective mixing height growth

!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 =  0   !

     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 = 40N  !
     (RLON0)                    No Default      ! RLON0 = 98W  !

         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 = 20N  !
(XLAT2)                   No Default      ! XLAT2 = 60N  !

    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 = NWS-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 = 313 !
       No. Y grid cells (NY)      No default     ! NY = 181 !

Grid spacing (DGRIDKM)            No default     ! DGRIDKM = 4. !
                                  Units: km

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

   X coordinate (XORIGKM)         No default     ! XORIGKM = -506. !
   Y coordinate (YORIGKM)         No default     ! YORIGKM =  298. !
                                  Units: km


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

   No. of vertical layers (NZ)    No default     ! NZ =  10  !

   Cell face heights in arbitrary
   vertical grid (ZFACE(NZ+1))    No defaults
                                  Units: m
! ZFACE = 0.,20.,40.,80.,160.,320.,640.,1200.,2000.,3000.,4000.  !
```

```
!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 =  10*0  !
       -----------------------


       Specify which levels of the W wind component to print
       (NOTE: W defined at TOP cell face --  10  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 =  10*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 =  10*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 =  1  !

          Print distance to land
          internal variables (LDBCST)      Default: F       ! LDBCST = F !
          (F = Do not print, T = print)
          (Output in .GRD file DCST.GRD, defined in input group 0)

       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 MM4/MM5/3D for upper air data
          2 = No surface, overwater, or upper air observations
              Use MM4/MM5/3D for surface, overwater, and upper air data

    NUMBER OF SURFACE & PRECIP. METEOROLOGICAL STATIONS

       Number of surface stations   (NSSTA)  No default     ! NSSTA = 250 !

       Number of precipitation stations
       (NPSTA=-1: flag for use of MM5/3D precip data)
                                    (NPSTA)  No default     ! NPSTA = 267 !

    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 computed from prognostic fields

    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 =  10*0  !

  Minimum distance from nearest upper air station
  to surface station for which extrapolation
  of surface winds at surface station will be allowed
  (RMIN2: Set to -1 for IEXTRP = 4 or other situations
   where all surface stations should be extrapolated)
                                        Default: 4.     ! RMIN2 = -1.0 !

  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 MM5/3D.DAT file as Step 1 field [IWFCOD = 0]
   14 = Yes, use winds from MM5/3D.DAT file as initial guess field [IWFCOD = 1]
   15 = Yes, use winds from MM5/3D.DAT file as observations [IWFCOD = 1]

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

  Use coarse CALMET fields as initial guess fields (IGFMET)
  (overwrites IGF based on prognostic wind fields if any)
                                        Default: 0      ! IGFMET =  0  !

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 = 100. !
                                        Units: km
  Maximum radius of influence over land
  aloft (RMAX2)                         No default      ! RMAX2 = 200. !
                                        Units: km
  Maximum radius of influence over water
  (RMAX3)                               No default      ! RMAX3 = 200. !
                                        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 = 15. !

                                        Units: km
  Relative weighting of the first
  guess field and observations in the
```

```
   SURFACE layer (R1)                     No default      ! R1 = 50. !
   (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 = 100. !
   (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 ,  9*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 = 10*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 = 10*0. !
   (Used only if IEXTRP = 3 or -3)


BARRIER INFORMATION

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

   Level (1 to NZ) up to which barriers
   apply (KBAR)                           Default: NZ     ! KBAR =  10  !

   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 =  211  !
   (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 =  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)


    CONVECTIVE MIXING HEIGHT OPTIONS:
       Method to compute the convective
       mixing height(IMIHXH)                Default: 1      ! IMIXH =  -1  !
           1: Maul-Carson for land and water cells
          -1: Maul-Carson for land cells only -
              OCD mixing height overwater
           2: Batchvarova and Gryning for land and water cells
          -2: Batchvarova and Gryning for land cells only
              OCD mixing height overwater
```

```
   Threshold buoyancy flux required to
   sustain convective mixing height growth
   overland (THRESHL)                    Default: 0.0    ! THRESHL = 0.0 !
   (expressed as a heat flux             units: W/m3
    per meter of boundary layer)


   Threshold buoyancy flux required to
   sustain convective mixing height growth
   overwater (THRESHW)                   Default: 0.05   ! THRESHW = 0.05 !
   (expressed as a heat flux             units: W/m3
    per meter of boundary layer)


   Option for overwater lapse rates used
   in convective mixing height growth
   (ITWPROG)                             Default: 0      ! ITWPROG =  0  !
   0 : use SEA.DAT lapse rates and deltaT (or assume neutral
       conditions if missing)
   1 : use prognostic lapse rates (only if IPROG>2)
       and SEA.DAT deltaT (or neutral if missing)
   2 : use prognostic lapse rates and prognostic delta T
       (only if iprog>12 and 3D.DAT version# 2.0 or higher)

   Land Use category ocean in 3D.DAT datasets
   (ILUOC3D)                             Default: 16     ! ILUOC3D =  16  !
   Note: if 3D.DAT from MM5 version 3.0, iluoc3d = 16
         if MM4.DAT,           typically iluoc3d = 7


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)


OVERWATER SURFACE FLUXES METHOD and PARAMETERS
      (ICOARE)                           Default: 10      ! ICOARE =  0   !
       0: original deltaT method (OCD)
      10: COARE with no wave parameterization (jwave=0, Charnock)
      11: COARE with wave option jwave=1 (Oost et al.)
          and default wave properties
     -11: COARE with wave option jwave=1 (Oost et al.)
          and observed wave properties (must be in SEA.DAT files)
      12: COARE with wave option 2 (Taylor and Yelland)
           and default wave properties
     -12: COARE with wave option 2 (Taylor and Yelland)
          and observed wave properties (must be in SEA.DAT files)

      Note:  When ICOARE=0, similarity wind profile stability PSI functions
             based on Van Ulden and Holtslag (1985) are substituted for
             later formulations used with the COARE module, and temperatures
             used for surface layer parameters are obtained from either the
             nearest surface station temperature or prognostic model 2D
             temperatures (if ITPROG=2).

      Coastal/Shallow water length scale (DSHELF)
      (for modified z0 in shallow water)
```

```
         ( COARE fluxes only)
                                          Default : 0.        ! DSHELF = 0. !
                                          units: km

          COARE warm layer computation (IWARM)                ! IWARM =  0   !
          1: on - 0: off (must be off if SST measured with
          IR radiometer)                  Default: 0

          COARE cool skin layer computation (ICOOL)           ! ICOOL =  0   !
          1: on - 0: off (must be off if SST measured with
          IR radiometer)                  Default: 0


    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 MM5/3D for upper air data
              (only if NOOBS = 0,1)
          2 = No surface or upper air observations
              Use MM5/3D 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          Units: K/m
       water (TGDEFB)

       Default temperature gradient          Default: -.0045   ! TGDEFA = -0.0045 !
       above the mixing height over          Units: K/m
       water (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  (SIGMAP)         Default: 100.0   ! SIGMAP = 100. !
        (0.0 => use half dist. btwn          Units: km
         nearest stns w & w/out
         precip when NFLAGP = 3)
       Minimum Precip. Rate Cutoff (CUTP)    Default: 0.01    ! CUTP = 0.01 !
        (values < CUTP = 0.0 mm/hr)          Units: mm/hr
!END!
-------------------------------------------------------------------------------
INPUT GROUP: 7 -- Surface meteorological station parameters
--------------

     SURFACE STATION VARIABLES
     (One record per station --  250  records in all)

             1     2
```

```
          Name   ID            X coord.   Y coord.   Time   Anem.
                                (km)       (km)      zone   Ht.(m)
       ----------------------------------------------------------
! SS1   ='CYBR',  711400,  -132.737961       1040.684570  7    10 !
! SS002 ='CWNK',  711470,    -2.262997        995.140137  7    10 !
! SS003 ='CWPO',  711480,   -62.049206        963.792969  7    10 !
! SS004 ='CWZE',  711700,   -91.927345       1038.115110  7    10 !
! SS005 ='CWDV',  714350,   520.234131        968.333252  7    10 !
! SS006 ='CWGN',  714410,    29.940273        945.930359  7    10 !
! SS007 ='CWEI',  714470,  -205.322525        975.742554  7    10 !
! SS008 ='CWSU',  714490,   165.977509        946.451843  7    10 !
! SS009 ='CWWF',  714520,  -396.077026       1029.438350  7    10 !
! SS010 ='EMER',  715600,    53.065262        942.609009  7    10 !
! SS011 ='CXMD',  715640,    -5.724126        961.681702  7    10 !
! SS012 ='WINN',  715790,    59.056881       1035.899780  7    10 !
! SS013 ='CZHD',  715820,   357.821838       1039.401120  7    10 !
! SS014 ='ATIK',  717470,   441.910736        933.946167  7    10 !
! SS015 ='CXDW',  718400,   -21.778795        984.620911  7    10 !
! SS016 ='CYHD',  718425,   358.876953       1041.158940  7    10 !
! SS017 ='CXWN',  718430,    59.056881       1035.899780  7    10 !
! SS018 ='WASP',  718490,    52.213905       1039.430420  7    10 !
! SS019 ='CYQK',  718500,   247.840500       1030.198360  7    10 !
! SS020 ='CYPG',  718510,   -18.181787       1037.431640  7    10 !
! SS021 ='CYWG',  718520,    52.229706       1037.633420  7    10 !
! SS022 ='CYEN',  718620,  -342.161255        975.010742  7    10 !
! SS023 ='KHZX',  720258,   337.785278        701.057190  7    10 !
! SS024 ='KFKA',  720283,   440.500244        398.718048  7    10 !
! SS025 ='KIIB',  720293,   465.955536        272.288361  7    10 !
! SS026 ='KVTI',  720326,   462.249084        247.538208  7    10 !
! SS027 ='KLUM',  720327,   454.199249        527.013367  7    10 !
! SS028 ='KCKP',  720344,   187.478500        287.882965  7    10 !
! SS029 ='KPEX',  720367,   239.019058        565.214783  7    10 !
! SS030 ='KDVP',  720368,   166.747665        418.091461  7    10 !
! SS031 ='KSYN',  722003,   371.754822        478.146027  7    10 !
! SS032 ='KBWP',  722004,   100.999161        653.452332  7    10 !
! SS033 ='KLYV',  722006,   134.958801        379.514679  7    10 !
! SS034 ='KACQ',  722032,   333.878906        433.998291  7    10 !
! SS035 ='KGDB',  722033,   181.560699        499.042145  7    10 !
! SS036 ='KCFE',  722114,   307.498352        545.390259  7    10 !
! SS037 ='KJKJ',  722129,    96.844124        715.808105  7    10 !
! SS038 ='KMGG',  722144,   296.022736        553.863770  7    10 !
! SS039 ='KOVL',  722168,   221.420837        503.003906  7    10 !
! SS040 ='KRNH',  722179,   403.259186        550.473206  7    10 !
! SS041 ='KRZN',  722183,   411.001251        621.797424  7    10 !
! SS042 ='KSFY',  722204,   611.118896        241.281296  7    10 !
! SS043 ='KLCG',  722241,    78.773186        234.543762  7    10 !
! SS044 ='KCNB',  722252,   128.874329        495.268707  7    10 !
! SS045 ='KTKC',  722342,   179.218750        446.241730  7    10 !
! SS046 ='KRCX',  723758,   513.212524        594.974731  7    10 !
! SS047 ='KAXA',  725457,   284.761230        327.492554  7    10 !
! SS048 ='KCAV',  725458,   325.802399        294.237671  7    10 !
! SS049 ='KMIW',  725461,   393.433167        232.077042  7    10 !
! SS050 ='KCCY',  725463,   411.742310        333.622681  7    10 !
! SS051 ='KCIN',  725468,   249.315628        218.213760  7    10 !
! SS052 ='KDBQ',  725470,   562.008728        273.891357  7    10 !
! SS053 ='KAMW',  725472,   339.960693        217.356750  7    10 !
! SS054 ='KMXO',  725475,   529.074829        252.985184  7    10 !
! SS055 ='KDEH',  725476,   476.241272        359.092377  7    10 !
! SS056 ='KEBS',  725478,   318.428436        261.887787  7    10 !
! SS057 ='KALO',  725480,   430.451233        280.485382  7    10 !
! SS058 ='KLRJ',  725484,   139.213089        291.510315  7    10 !
! SS059 ='KMCW',  725485,   355.652557        339.276703  7    10 !
! SS060 ='KBNW',  725486,   322.820679        221.638809  7    10 !
! SS061 ='KOLZ',  725488,   462.849091        295.942047  7    10 !
! SS062 ='KORC',  725489,   148.912033        313.869507  7    10 !
! SS063 ='KFOD',  725490,   284.697876        278.665985  7    10 !
! SS064 ='KSHL',  725495,   164.999420        337.029449  7    10 !
! SS065 ='KSLB',  725496,   212.618134        274.528046  7    10 !
! SS066 ='KANW',  725556,  -152.562332        271.011780  7    10 !
! SS067 ='KONL',  725566,   -52.690170        258.100037  7    10 !
! SS068 ='KSUX',  725570,   125.017456        250.804749  7    10 !
! SS069 ='KAIA',  725635,  -371.946045        225.001831  7    10 !
! SS070 ='KCDR',  725636,  -390.018555        307.721893  7    10 !
! SS071 ='KVTN',  725670,  -195.296432        301.377747  7    10 !
```

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! SS072 ='KTOR',  725763,  -476.574402        232.416214   7    10 !
! SS073 ='KLNR',  726416,   594.580078        362.063934   7    10 !
! SS074 ='KMDZ',  726417,   567.921021        557.987793   7    10 !
! SS075 ='KOEO',  726418,   390.745178        566.480835   7    10 !
! SS076 ='KASX',  726419,   510.271820        705.353516   7    10 !
! SS077 ='KSUW',  726427,   424.747314        713.702942   7    10 !
! SS078 ='KLSE',  726430,   508.635651        411.707031   7    10 !
! SS079 ='KEAU',  726435,   482.727417        526.252747   7    10 !
! SS080 ='KVOK',  726436,   581.265625        437.046356   7    10 !
! SS081 ='KCMY',  726437,   546.142822        436.117981   7    10 !
! SS082 ='KOVS',  726438,   557.368958        352.953308   7    10 !
! SS083 ='KRST',  726440,   414.564484        420.806641   7    10 !
! SS084 ='KPDC',  726444,   525.151245        335.964905   7    10 !
! SS085 ='KAQP',  726466,   146.927185        547.887634   7    10 !
! SS086 ='KRPD',  726467,   457.289001        582.535217   7    10 !
! SS087 ='KPBH',  726468,   555.096680        620.769592   7    10 !
! SS088 ='KEST',  726499,   246.954147        360.483246   7    10 !
! SS089 ='KSPW',  726500,   213.177475        333.802368   7    10 !
! SS090 ='KMRJ',  726507,   593.426697        327.873383   7    10 !
! SS091 ='KHYR',  726508,   476.630768        647.714050   7    10 !
! SS092 ='KFSD',  726510,    94.328735        374.210144   7    10 !
! SS093 ='KCUT',  726514,  -424.749512        403.337982   7    10 !
! SS094 ='KBKX',  726515,    89.727325        450.046783   7    10 !
! SS095 ='KPHP',  726516,  -270.501099        428.665131   7    10 !
! SS096 ='KIEN',  726517,  -344.901764        324.377960   7    10 !
! SS097 ='KICR',  726518,  -139.856018        355.472290   7    10 !
! SS098 ='K8D3',  726519,    73.856110        592.815918   7    10 !
! SS099 ='KYKN',  726525,    47.198750        304.747040   7    10 !
! SS100 ='K9V9',  726530,   -99.478973        394.145111   7    10 !
! SS101 ='KD07',  726539,  -297.153381        532.540222   7    10 !
! SS102 ='KHON',  726540,   -17.115011        458.027527   7    10 !
! SS103 ='KORB',  726544,   362.149048        849.423584   7    10 !
! SS104 ='KMHE',  726545,    -2.867938        394.439606   7    10 !
! SS105 ='KATY',  726546,    62.674583        515.427490   7    10 !
! SS106 ='KGHW',  726547,   196.441757        592.791626   7    10 !
! SS107 ='KRRT',  726548,   184.543518        938.973633   7    10 !
! SS108 ='KCQM',  726549,   374.770538        829.738953   7    10 !
! SS109 ='KSTC',  726550,   289.477570        585.952942   7    10 !
! SS110 ='KMVE',  726553,   170.196106        521.343323   7    10 !
! SS111 ='KJYG',  726554,   258.831940        421.393066   7    10 !
! SS112 ='KBRD',  726555,   279.693115        675.731506   7    10 !
! SS113 ='KRWF',  726556,   217.481979        478.586823   7    10 !
! SS114 ='KAXN',  726557,   190.130997        617.650024   7    10 !
! SS115 ='KCOQ',  726558,   395.496307        713.259888   7    10 !
! SS116 ='KMML',  726559,   162.968735        466.842621   7    10 !
! SS117 ='KFFM',  726560,   133.957138        658.783936   7    10 !
! SS118 ='KADC',  726561,   202.232361        677.177307   7    10 !
! SS119 ='KLVN',  726562,   355.831726        493.177429   7    10 !
! SS120 ='KFBL',  726563,   351.367981        461.196899   7    10 !
! SS121 ='KRGK',  726564,   410.713379        492.334595   7    10 !
! SS122 ='KMOX',  726565,   149.050827        583.337769   7    10 !
! SS123 ='KPQN',  726566,   127.867722        417.218353   7    10 !
! SS124 ='KULM',  726567,   261.794373        456.355988   7    10 !
! SS125 ='KOWA',  726568,   356.252655        440.308838   7    10 !
! SS126 ='KHCD',  726569,   269.311188        513.197021   7    10 !
! SS127 ='KMFI',  726574,   580.651794        510.377930   7    10 !
! SS128 ='KMIC',  726575,   343.520233        538.094177   7    10 !
! SS129 ='KILL',  726576,   215.343185        538.084961   7    10 !
! SS130 ='KANE',  726577,   354.121063        547.264282   7    10 !
! SS131 ='KLXL',  726578,   267.035187        627.336975   7    10 !
! SS132 ='KFCM',  726579,   335.989746        513.490601   7    10 !
! SS133 ='KMSP',  726580,   353.555969        519.771912   7    10 !
! SS134 ='KLJF',  726583,   258.245758        542.910095   7    10 !
! SS135 ='KSTP',  726584,   366.675781        525.429749   7    10 !
! SS136 ='KMKT',  726585,   305.851746        448.014862   7    10 !
! SS137 ='KFRM',  726586,   270.888275        386.311646   7    10 !
! SS138 ='KOTG',  726587,   183.869949        384.251251   7    10 !
! SS139 ='KONA',  726588,   472.697937        442.873871   7    10 !
! SS140 ='KAEL',  726589,   350.012085        393.702515   7    10 !
! SS141 ='KMJQ',  726593,   228.025085        385.108063   7    10 !
! SS142 ='KTOB',  726596,   389.349762        431.199585   7    10 !
! SS143 ='KSGS',  726603,   369.330719        517.929749   7    10 !
! SS144 ='KRAP',  726620,  -379.573975        433.557648   7    10 !
! SS145 ='KRCA',  726625,  -382.719269        444.108978   7    10 !
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! SS146 ='K2WX',  726627,  -406.119324        598.495300   7    10 !
! SS147 ='KGDV',  726676,  -485.291168        764.848572   7    10 !
! SS148 ='KROS',  726679,   369.271759        606.119019   7    10 !
! SS149 ='KPNM',  726682,   321.927612        589.078491   7    10 !
! SS150 ='KMBG',  726685,  -176.595627        581.943726   7    10 !
! SS151 ='KPIR',  726686,  -170.840286        460.034729   7    10 !
! SS152 ='KBHK',  726777,  -451.931519        680.796631   7    10 !
! SS153 ='KTWM',  727444,   447.882660        753.196777   7    10 !
! SS154 ='KIWD',  727445,   568.052795        708.005310   7    10 !
! SS155 ='KMZH',  727449,   375.724762        682.198181   7    10 !
! SS156 ='KDLH',  727450,   416.484497        729.449829   7    10 !
! SS157 ='KCKN',  727452,    97.614517        821.203613   7    10 !
! SS158 ='KPKD',  727453,   210.237167        725.100281   7    10 !
! SS159 ='KCKC',  727454,   538.050964        843.562256   7    10 !
! SS160 ='KHIB',  727455,   366.902435        783.460327   7    10 !
! SS161 ='KDYT',  727456,   428.819427        717.451233   7    10 !
! SS162 ='KDTL',  727457,   152.005173        715.434570   7    10 !
! SS163 ='KGPZ',  727458,   322.304291        757.524109   7    10 !
! SS164 ='KELO',  727459,   436.137146        833.787537   7    10 !
! SS165 ='KDXX',  727466,   135.592072        522.303162   7    10 !
! SS166 ='KFGN',  727467,   213.240936        979.714966   7    10 !
! SS167 ='KFOZ',  727468,   307.224548        821.887573   7    10 !
! SS168 ='KGNA',  727469,   540.576965        834.178345   7    10 !
! SS169 ='KINL',  727470,   320.312805        905.074768   7    10 !
! SS170 ='KCDD',  727473,   386.335419        877.262329   7    10 !
! SS171 ='KEVM',  727474,   391.790405        788.879883   7    10 !
! SS172 ='KJMR',  727475,   345.046997        624.486511   7    10 !
! SS173 ='KBDE',  727476,   235.597336        918.279846   7    10 !
! SS174 ='KROX',  727477,   160.620377        929.324951   7    10 !
! SS175 ='KHCO',  727478,    74.069351        916.788330   7    10 !
! SS176 ='KVWU',  727486,   244.470413        858.134155   7    10 !
! SS177 ='KXVG',  727497,   272.035095        736.835632   7    10 !
! SS178 ='KCBG',  727503,   348.076263        590.344666   7    10 !
! SS179 ='KAIT',  727504,   312.392944        692.284912   7    10 !
! SS180 ='KFSE',  727505,   158.197388        796.274719   7    10 !
! SS181 ='KMWM',  727506,   218.269440        412.281738   7    10 !
! SS182 ='KBBB',  727507,   172.873306        559.424866   7    10 !
! SS183 ='KPWC',  727508,   260.166504        708.491943   7    10 !
! SS184 ='KSAZ',  727514,   231.012894        671.240906   7    10 !
! SS185 ='KVVV',  727515,   116.557121        555.432495   7    10 !
! SS186 ='KGYL',  727517,   292.026825        503.395447   7    10 !
! SS187 ='KFAR',  727530,    85.235794        724.666626   7    10 !
! SS188 ='KETH',  727533,   107.109177        604.916931   7    10 !
! SS189 ='KJMS',  727535,   -48.600674        724.799500   7    10 !
! SS190 ='KBJI',  727550,   217.668808        789.249329   7    10 !
! SS191 ='KTVF',  727555,   127.754288        845.218018   7    10 !
! SS192 ='KBFW',  727556,   470.053284        775.894714   7    10 !
! SS193 ='KAUM',  727566,   382.861328        393.856171   7    10 !
! SS194 ='KDVL',  727573,   -63.301125        849.265076   7    10 !
! SS195 ='KRDR',  727575,    42.193775        833.090881   7    10 !
! SS196 ='KGFK',  727576,    58.054287        831.958191   7    10 !
! SS197 ='KHEI',  727584,  -338.650360        637.574768   7    10 !
! SS198 ='KBIS',  727640,  -197.468048        711.348206   7    10 !
! SS199 ='KDIK',  727645,  -344.816040        720.144897   7    10 !
! SS200 ='KISN',  727670,  -395.559692        870.364624   7    10 !
! SS201 ='KMIB',  727675,  -234.574783        887.034424   7    10 !
! SS202 ='KMOT',  727676,  -229.883179        868.627991   7    10 !
! SS203 ='KN60',  727677,  -243.419296        806.407776   7    10 !
! SS204 ='KSDY',  727687,  -437.134430        821.736145   7    10 !
! SS205 ='DB21',  992130,   569.102051        789.578186   7    10 !
! SS206 ='DISW',  994190,   518.981140        762.303711   7    10 !
! SS207 ='GDMM',  997259,   541.324097        834.560608   7    10 !
! SS208 ='DULM',  997269,   208.355286        712.645996   7    10 !
! SS209 ='SLVM',  997737,   492.508667        779.533997   7    10 !
! SS210 ='SXHW',  997738,   545.045349        710.175049   7    10 !
! SS211 ='KABR',   14929,   -30.927084        569.527222   7    10 !
! SS212 ='CXCA',  712910,   665.708           995.123      7    10 !
! SS213 ='CWKK',  714680,   659.087          1054.620      7    10 !
! SS214 ='CZTB',  716670,   605.270           905.768      7    10 !
! SS215 ='CYQT',  717490,   606.384           905.880      7    10 !
! SS216 ='CWEC',  717510,   620.303           907.286      7    10 !
! SS217 ='KPCZ',  720343,   670.534           487.112      7    10 !
! SS218 ='KBUU',  722059,   743.135           322.231      7    10 !
! SS219 ='KFEP',  722082,   650.792           265.980      7    10 !
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! SS220 ='KTKV',  722332,   600.874           599.685      7    10 !
! SS221 ='KLNL',  723123,   637.072           675.329      7    10 !
! SS222 ='KRFD',  725430,   687.861           264.429      7    10 !
! SS223 ='KARV',  726404,   602.749           648.160      7    10 !
! SS224 ='KMWC',  726405,   758.425           368.114      7    10 !
! SS225 ='KUES',  726409,   744.074           359.229      7    10 !
! SS226 ='KMSN',  726410,   658.688           360.685      7    10 !
! SS227 ='KETB',  726413,   748.375           399.775      7    10 !
! SS228 ='KEFT',  726414,   645.849           304.217      7    10 !
! SS229 ='KJVL',  726415,   687.411           308.790      7    10 !
! SS230 ='KSTE',  726426,   631.316           505.457      7    10 !
! SS231 ='KRRL',  726449,   611.236           572.272      7    10 !
! SS232 ='KGRB',  726450,   735.334           513.081      7    10 !
! SS233 ='KISW',  726452,   609.461           483.824      7    10 !
! SS234 ='KOSH',  726456,   708.916           454.486      7    10 !
! SS235 ='KATW',  726457,   708.810           483.186      7    10 !
! SS236 ='KAUW',  726463,   619.378           544.664      7    10 !
! SS237 ='KRYV',  726464,   705.542           368.458      7    10 !
! SS238 ='KCWA',  726465,   617.935           528.652      7    10 !
! SS239 ='KCLI',  726502,   688.915           518.593      7    10 !
! SS240 ='KDLL',  726503,   622.616           397.178      7    10 !
! SS241 ='KEGV',  726504,   635.279           651.763      7    10 !
! SS242 ='KFLD',  726506,   716.660           432.829      7    10 !
! SS243 ='KUNU',  726509,   704.428           395.344      7    10 !
! SS244 ='KAIG',  726626,   655.759           571.941      7    10 !
! SS245 ='KRHI',  727415,   624.144           618.968      7    10 !
! SS246 ='KIMT',  727437,   720.330           648.861      7    10 !
! SS247 ='KCMX',  727440,   676.490           786.555      7    10 !
! SS248 ='PILM',  994090,   674.212           897.149      7    10 !
! SS249 ='ROAM',  994130,   611.612           853.525      7    10 !
! SS250 ='PCLM',  997732,   673.459           796.578      7    10 !
-------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Six digit integer for station ID
!END!
-------------------------------------------------------------------------------
INPUT GROUP: 8 -- Upper air meteorological station parameters
--------------

     UPPER AIR STATION VARIABLES
     (One record per station --  10  records in all)

             1     2
         Name    ID      X coord.   Y coord.  Time zone
                           (km)       (km)
        --------------------------------------------------------
! US1  ='ABR'   14929    -30.853664   569.526855   7  !
! US2  ='BIS'   24011   -197.624863   710.933411   7  !
! US3  ='DVN'   94982    579.394958   191.740204   7  !
! US4  ='GGW'   94008   -603.732971   887.948792   7  !
! US5  ='GRB'   14898    734.982605   509.566772   7  !
! US6  ='INL'   14918    321.891815   905.579956   7  !
! US7  ='LBF'   24023   -210.715042   121.217461   7  !
! US8  ='MPX'   94983    330.071899   512.976318   7  !
! US9  ='OAX'   94980    127.800606   139.010620   7  !
! US0 = 'UNR'   94043   -391.126526   436.751404   7  !

-------------------
      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 --  267  records in all)
(NOT INCLUDED IF NPSTA = 0)

          1          2
     Name   Station    X coord.  Y coord.
              Code       (km)      (km)
     ----------------------------------
! PS1   ='BVDI', 110583,    704.8387    272.3856   !
! PS002 ='FEEI', 113262,    647.5109    271.0132   !
! PS003 ='LNKI', 114879,    631.2090    247.9581   !
! PS004 ='MHYI', 115493,    751.1465    283.1947   !
! PS005 ='KRFD', 117382,    687.8933    264.1178   !
! PS006 ='AMSI', 130200,    327.6863    218.9460   !
! PS007 ='BLVI', 130608,    584.8422    261.4843   !
! PS008 ='BYRI', 130853,    217.6606    225.4780   !
! PS009 ='CASI', 131257,    539.0943    261.5334   !
! PS010 ='CCTI', 131363,    500.1082    248.3606   !
! PS011 ='CKPI', 131442,    188.7850    290.5321   !
! PS012 ='KDBQ', 132367,    562.0087    273.8914   !
! PS013 ='FSCI', 132977,    332.1617    351.2404   !
! PS014 ='HORI', 133944,    148.3817    226.7336   !
! PS015 ='HBTI', 133980,    289.6530    290.3780   !
! PS016 ='IDGI', 134038,    191.6283    252.6864   !
! PS017 ='IWAI', 134142,    365.1421    272.9465   !
! PS018 ='MSHI', 135198,    393.2604    227.0463   !
! PS019 ='KMCW', 135235,    355.9792    338.8755   !
! PS020 ='MGGI', 135315,    520.6938    336.1376   !
! PS021 ='MOVI', 135823,    148.6746    262.4633   !
! PS022 ='OCHI', 136190,    187.3795    359.1556   !
! PS023 ='OGDI', 136209,    306.8351    219.8488   !
! PS024 ='REMI', 136975,    155.4437    295.9428   !
! PS025 ='RINI', 137058,    265.1759    349.3717   !
! PS026 ='RWCI', 137167,    259.9339    254.6663   !
! PS027 ='SANI', 137326,    385.8669    364.4076   !
! PS028 ='SHFI', 137572,    360.6382    314.8558   !
! PS029 ='SHRI', 137602,    413.0282    295.5028   !
! PS030 ='SIBI', 137664,    173.7475    363.5918   !
! PS031 ='SIXI', 137700,    140.9742    320.5928   !
! PS032 ='KSUX', 137708,    125.0175    250.8047   !
! PS033 ='K3SE', 137844,    217.3630    334.0425   !
! PS034 ='SPLI', 137855,    460.0540    350.6164   !
! PS035 ='STYI', 137985,    341.7265    236.1608   !
! PS036 ='SPTI', 138009,    495.9100    298.6285   !
! PS037 ='TREI', 138315,    427.3502    241.8837   !
! PS038 ='KALO', 138706,    430.4512    280.4854   !
! PS039 ='WEBI', 138806,    323.6514    265.5879   !
! PS040 ='ALBM', 200089,    684.2539    732.0740   !
! PS041 ='BRUM', 201088,    635.1568    715.0804   !
! PS042 ='IRNM', 204090,    722.8865    645.7775   !
! PS043 ='KENM', 204328,    657.2375    712.0861   !
! PS044 ='ONGM', 206215,    622.5252    747.8704   !
! PS045 ='STMM', 207812,    680.3516    669.5223   !
! PS046 ='WAKM', 208559,    581.8848    704.2177   !
! PS047 ='ALBM', 210075,    355.3395    386.1382   !
! PS048 ='KAXN', 210112,    190.1019    616.1816   !
! PS049 ='AXNM', 210116,    192.0553    619.1755   !
! PS050 ='AMBM', 210157,    288.7599    411.9700   !
! PS051 ='BGFM', 210746,    294.6127    864.8739   !
! PS052 ='BKKM', 210973,    102.1184    655.9871   !
! PS053 ='BUFM', 211107,    303.8945    548.1531   !
! PS054 ='CMBM', 211227,    357.2755    590.0135   !
! PS055 ='RLWM', 211250,    196.2616    904.4382   !
! PS056 ='CANM', 211263,    128.1724    493.1620   !
! PS057 ='DDGM', 212166,    384.4749    433.4247   !
! PS058 ='KDLH', 212248,    417.3215    728.7693   !
! PS059 ='ELYM', 212543,    432.4948    844.2844   !
! PS060 ='ELVM', 212645,    388.3740    792.2442   !
! PS061 ='FLDM', 212842,    367.2563    739.9268   !
! PS062 ='FSSM', 212916,    161.3947    793.3084   !
! PS063 ='FRZM', 212964,    164.9626    706.2097   !
! PS064 ='GOLM', 213202,    339.6924    530.6596   !
! PS065 ='GDPM', 213296,    584.3096    861.8482   !
! PS066 ='GTEM', 213311,    181.4707    504.9010   !
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! PS067 ='GLLM', 213411,    263.0453    675.7494   !
! PS068 ='GNFM', 213417,    498.9962    874.2490   !
! PS069 ='HLSM', 213463,     82.9847    769.6907   !
! PS070 ='HLYM', 213863,    404.9866    689.0575   !
! PS071 ='HSNM', 213962,    269.0934    518.4244   !
! PS072 ='KINL', 214026,    320.6607    905.0931   !
! PS073 ='LCRM', 214418,    503.6740    423.0656   !
! PS074 ='LKFM', 214453,    215.1507    390.1127   !
! PS075 ='FEDM', 214652,    269.2213    763.7258   !
! PS076 ='LESM', 214721,    305.6771    474.0750   !
! PS077 ='LTFM', 214793,    265.6005    631.9966   !
! PS078 ='LUVM', 214937,    135.9208    384.2386   !
! PS079 ='MRSM', 215175,    307.8797    805.9199   !
! PS080 ='KMSP', 215435,    353.5560    519.7719   !
! PS081 ='NRFM', 215987,    360.9039    478.3724   !
! PS082 ='ONMM', 216166,    314.9640    642.0206   !
! PS083 ='ORWM', 216228,    132.1633    650.9859   !
! PS084 ='PKGM', 216612,    314.5689    766.2769   !
! PS085 ='RIAM', 216795,    210.4573    827.7108   !
! PS086 ='RDWM', 216822,    401.1355    493.9360   !
! PS087 ='KRST', 217004,    414.0315    420.8777   !
! PS088 ='RUDM', 217184,    471.0624    414.2486   !
! PS089 ='KSTC', 217294,    289.5603    585.7471   !
! PS090 ='SDYM', 217460,    336.0036    719.4551   !
! PS091 ='SHRM', 217602,    243.9724    383.5873   !
! PS092 ='SPFM', 217907,    225.7181    447.4742   !
! PS093 ='SPRM', 217917,    482.1662    394.8293   !
! PS094 ='SPGM', 217941,    423.4222    399.2727   !
! PS095 ='TLRM', 218235,    142.8105    889.9860   !
! PS096 ='TOFM', 218280,    506.4730    812.3920   !
! PS097 ='TCYM', 218323,    177.4506    445.1472   !
! PS098 ='TWNM', 218411,    121.8223    756.6730   !
! PS099 ='WALM', 218613,    448.5977    775.0430   !
! PS100 ='WAKM', 218621,    244.9690    747.1674   !
! PS101 ='WRRM', 218679,    186.0316    935.6436   !
! PS102 ='WTSM', 218729,    163.5419    526.7195   !
! PS103 ='WHRM', 218947,    104.7027    613.4695   !
! PS104 ='WLLM', 219004,    220.1296    540.7602   !
! PS105 ='WNBM', 219059,    280.0303    783.5529   !
! PS106 ='KOTG', 219170,    182.9918    383.1815   !
! PS107 ='ALZM', 240165,   -473.8755    541.4405   !
! PS108 ='EKLM', 242689,   -476.9735    633.4473   !
! PS109 ='GNDM', 243581,   -479.6689    761.5683   !
! PS110 ='ISMM', 244442,   -490.4647    698.6182   !
! PS111 ='PTWM', 246589,   -452.8222    937.0795   !
! PS112 ='WSBM', 248777,   -419.1858    943.3163   !
! PS113 ='AMEN', 250180,    -73.5246    233.7535   !
! PS114 ='BSTN', 250580,   -118.4281    270.1134   !
! PS115 ='CLEN', 251776,     60.8985    261.9291   !
! PS116 ='CFTN', 252049,     40.3591    297.2858   !
! PS117 ='HRRN', 253620,   -464.1168    293.2032   !
! PS118 ='LYNN', 255040,    -35.0843    295.4801   !
! PS119 ='PNDN', 256630,    100.2274    221.5656   !
! PS120 ='PIRN', 256720,     37.0557    229.3818   !
! PS121 ='ROYN', 257351,     -7.7141    248.3947   !
! PS122 ='KVTN', 258760,   -195.1619    303.3590   !
! PS123 ='WAYN', 259050,     72.8387    240.0117   !
! PS124 ='WHIN', 259262,   -265.8226    222.7091   !
! PS125 ='ADMN', 320022,     -8.3296    871.8898   !
! PS126 ='AMBN', 320189,   -379.4584    954.1055   !
! PS127 ='ALYN', 320382,   -100.2561    631.6342   !
! PS128 ='BLDN', 320450,     -5.9390    735.8462   !
! PS129 ='BFRN', 320492,   -180.9230    831.2956   !
! PS130 ='KBIS', 320819,   -198.0849    712.3129   !
! PS131 ='BOWN', 320995,   -392.1297    658.3008   !
! PS132 ='CAON', 321288,    -82.5768    888.9763   !
! PS133 ='CRNN', 321362,    -79.5731    785.9337   !
! PS134 ='CVLN', 321435,     20.7365    927.9660   !
! PS135 ='DAWN', 322018,   -125.4999    719.1512   !
! PS136 ='KDIK', 322183,   -344.4455    720.3346   !
! PS137 ='DCKN', 322188,   -344.9175    730.0309   !
! PS138 ='KFAR', 322859,     85.2358    724.6666   !
! PS139 ='GLNN', 323496,   -275.0014    718.2638   !
! PS140 ='GRAN', 323594,     40.1860    881.1769   !
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! PS141 ='KGFK', 323616,     57.4969    831.3218   !
! PS142 ='GRFN', 323621,     63.5791    829.1727   !
! PS143 ='HFDN', 323926,    -13.2475    764.6330   !
! PS144 ='HZTN', 324083,   -169.5298    683.5571   !
! PS145 ='HETN', 324180,   -338.1250    636.4974   !
! PS146 ='KJMS', 324413,    -47.9586    724.3745   !
! PS147 ='LNGN', 324958,    -23.9686    917.3320   !
! PS148 ='LDSN', 325078,   -100.3021    868.1802   !
! PS149 ='MESN', 325479,   -208.9686    715.8164   !
! PS150 ='MCGN', 325720,   -343.1684    909.5942   !
! PS151 ='KMOT', 325988,   -229.3390    868.1865   !
! PS152 ='MNON', 325993,   -231.3919    860.2588   !
! PS153 ='MONN', 326105,    -42.0241    700.6135   !
! PS154 ='MTTN', 326155,   -312.1531    673.7914   !
! PS155 ='OAKN', 326620,     -6.4662    639.6499   !
! PS156 ='PBAN', 326947,     52.6743    939.8636   !
! PS157 ='RAUN', 327405,   -284.0016    823.9304   !
! PS158 ='RDTN', 327530,   -309.6853    727.9753   !
! PS159 ='RIVN', 327585,   -239.5621    788.9016   !
! PS160 ='RTEN', 327655,   -125.2927    906.5640   !
! PS161 ='SRLN', 327844,    -68.9054    936.9689   !
! PS162 ='TWNN', 328792,   -167.2207    878.3873   !
! PS163 ='TRON', 328812,   -420.1660    775.9999   !
! PS164 ='TUTN', 328853,   -136.6915    765.0718   !
! PS165 ='WTGN', 329219,   -259.4384    634.7834   !
! PS166 ='KISN', 329425,   -395.3525    868.1364   !
! PS167 ='WTON', 329455,   -199.0533    751.7303   !
! PS168 ='KABR', 390020,    -30.3432    568.7914   !
! PS169 ='BROS', 391076,     92.1705    451.9631   !
! PS170 ='CACS', 391294,   -437.8077    594.8177   !
! PS171 ='CPRS', 391452,      8.2556    489.8082   !
! PS172 ='CWDS', 391972,   -290.4360    420.1009   !
! PS173 ='EMTS', 392557,   -444.1663    359.8992   !
! PS174 ='EGMS', 392565,   -447.2860    393.6244   !
! PS175 ='FAIS', 392852,   -298.5418    531.3470   !
! PS176 ='GTYS', 393302,   -164.0811    525.8958   !
! PS177 ='HOWS', 394037,     35.7884    419.1016   !
! PS178 ='KHON', 394127,    -16.6633    459.3860   !
! PS179 ='INTS', 394184,   -297.4555    398.1286   !
! PS180 ='ISAS', 394268,   -252.1393    568.5466   !
! PS181 ='LNRS', 394651,   -271.9312    329.3606   !
! PS182 ='LKSS', 394766,   -109.6760    425.3580   !
! PS183 ='LEMS', 394864,   -302.8922    628.0018   !
! PS184 ='MCIS', 395381,   -239.2239    614.5892   !
! PS185 ='MNOS', 395481,     32.6538    337.9855   !
! PS186 ='MVLS', 395544,   -269.8144    477.8271   !
! PS187 ='MSSS', 395620,   -201.9105    348.2929   !
! PS188 ='MURS', 395891,   -203.9713    409.3122   !
! PS189 ='PIES', 396170,   -180.5313    466.4690   !
! PS190 ='ONKS', 396282,   -108.4420    547.5420   !
! PS191 ='ORLS', 396304,   -399.6830    367.4265   !
! PS192 ='RAPS', 396427,   -411.5727    437.1682   !
! PS193 ='PKSS', 396574,    -40.6760    320.5826   !
! PS194 ='KPIR', 396597,   -170.8458    459.8257   !
! PS195 ='PNVS', 396636,   -312.4171    483.0867   !
! PS196 ='KRAP', 396937,   -379.5922    433.2443   !
! PS197 ='K3DE', 397052,    -38.9352    508.4391   !
! PS198 ='EROS', 397662,    103.6776    391.1785   !
! PS199 ='FSDS', 397666,     96.1284    375.3860   !
! PS200 ='KFSD', 397667,     94.3272    374.3146   !
! PS201 ='SPES', 397882,   -437.6306    486.2325   !
! PS202 ='STPS', 397992,   -112.4635    446.7385   !
! PS203 ='STKS', 398007,    -33.0744    375.5005   !
! PS204 ='VRMS', 398622,     82.8919    289.0081   !
! PS205 ='KATY', 398932,     63.0713    512.7103   !
! PS206 ='WNRS', 398980,     48.2724    568.4824   !
! PS207 ='WNDS', 399347,   -414.0301    384.8526   !
! PS208 ='AFTW', 470045,    685.2767    311.5101   !
! PS209 ='ALMW', 470124,    454.5445    467.7898   !
! PS210 ='ARLW', 470308,    658.3940    377.4543   !
! PS211 ='AEFW', 470349,    506.3299    707.5601   !
! PS212 ='BBCW', 470456,    588.1370    475.5576   !
! PS213 ='BLKW', 470855,    534.3033    469.9684   !
! PS214 ='BVLW', 470890,    622.5366    323.1918   !
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! PS215 ='CHMW', 471416,    649.4243    351.2666   !
! PS216 ='CHIW', 471568,    738.9901    462.9800   !
! PS217 ='CHFW', 471578,    487.9245    533.2549   !
! PS218 ='CLIW', 471667,    700.7871    302.8314   !
! PS219 ='CNTW', 471676,    687.5571    519.3958   !
! PS220 ='CRIW', 471897,    720.0029    600.3361   !
! PS221 ='CBCW', 471913,    578.7880    299.1148   !
! PS222 ='EPLW', 472447,    611.8039    522.4976   !
! PS223 ='FRSW', 472973,    613.6624    443.8912   !
! PS224 ='GENW', 473038,    512.1511    392.7966   !
! PS225 ='KGRB', 473269,    734.4010    509.3955   !
! PS226 ='HARW', 473453,    727.3196    387.8478   !
! PS227 ='HYRW', 473511,    472.1889    644.6486   !
! PS228 ='THRW', 473636,    660.4031    627.8968   !
! PS229 ='HORW', 473756,    709.3147    397.4457   !
! PS230 ='KLSE', 474370,    507.8517    424.7510   !
! PS231 ='KARX', 474373,    512.9490    419.4862   !
! PS232 ='LADW', 474396,    507.2212    588.8231   !
! PS233 ='LAFW', 474404,    556.4146    396.8088   !
! PS234 ='LANW', 474546,    551.7680    318.1030   !
! PS235 ='LUCW', 474894,    404.0576    595.1112   !
! PS236 ='LYNW', 474937,    524.9281    356.1731   !
! PS237 ='KMSN', 474961,    658.6881    360.6846   !
! PS238 ='MFDW', 475120,    584.9993    510.2444   !
! PS239 ='MEDW', 475255,    564.6284    560.8494   !
! PS240 ='MENW', 475335,    449.3014    524.7825   !
! PS241 ='MERW', 475352,    574.7755    670.8159   !
! PS242 ='RRLW', 475364,    614.4525    569.6350   !
! PS243 ='MNGW', 475524,    448.9307    653.5699   !
! PS244 ='NRIW', 475948,    401.2504    547.0966   !
! PS245 ='PKFW', 476398,    549.4885    643.9443   !
! PS246 ='PHEW', 476518,    647.8389    667.1542   !
! PS247 ='PORW', 476718,    647.9724    400.2571   !
! PS248 ='PRNW', 476854,    564.8926    604.7028   !
! PS249 ='LTKW', 476939,    615.9632    639.5358   !
! PS250 ='RILW', 477132,    457.3847    582.2273   !
! PS251 ='RRVW', 477140,    604.4020    607.5921   !
! PS252 ='SPOW', 478027,    446.7621    624.3160   !
! PS253 ='STMW', 478259,    492.2289    488.2560   !
! PS254 ='KMKX', 478316,    720.9299    348.8920   !
! PS255 ='TOMW', 478515,    563.0179    441.0115   !
! PS256 ='TREW', 478589,    493.0102    436.1974   !
! PS257 ='WLKW', 479176,    682.3917    577.6713   !
! PS258 ='WLDW', 479218,    540.3058    516.7501   !
! PS259 ='WTRW', 479304,    509.5294    628.9366   !
! PS260 ='DLCW', 482725,   -527.8164    377.3655   !
! PS261 ='LCKW', 485371,   -508.2396    336.7448   !
! PS262 ='MCTW', 486395,   -518.7186    461.0498   !
! PS263 ='MCKW', 486603,   -472.6974    370.2560   !
! PS264 ='NCLW', 486660,   -467.9591    419.5807   !
! PS265 ='OSGW', 486935,   -482.4476    433.2086   !
! PS266 ='TORW', 488995,   -481.9526    234.3690   !
! PS267 ='WLDW', 489615,   -537.7224    241.8340   !

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      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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