Alberta's Air Quality Model Guideline and Meteorological Dataset: Update 2021

CPANS

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Air Policy
October 28, 2021

Alberta's Air Quality Model Guideline and Meteorological Data: Update 2021

Alberta's Air Quality Model Guideline (and response document)

Location:
https://open.alberta.ca/publications/air-quality-model-guideline-2021

Meteorological Dataset
Location:
https://www.alberta.ca/meteorological-data-for-dispersion-models

Contact:
AEP.AirQltyModels@gov.ab.ca

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Alberta's Air Quality Model Guideline: Update 2021

Modelling Approach

- **Level of refinement**
- **Scenarios**
- **Source types**
- **Baseline**
- **Surface characteristics**

Model Output

- **Sub/super-hourly averaging times**
- **Chemistry:**
  - **NO_2/NO_x conversion**
  - **TRS**
  - **Other chemistry**
- **Acid deposition**

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Modelling Approach

Level of Refinement

Screening – simple cases/preliminary look at problem/nearby sources

Refined/Advanced – consider terrain/alternate switches

Alternate – specialized/one of

Note: Not tiered

Table 1 Assessment Level and Corresponding Acceptable Air Quality Model(s)

Air Quality Assessment	Approved Air Quality Model	Restrictions			
		Switches	Model Domain	Meteorology	Other
Screening	AERSCREEN		≤ 50 km	MAKEMET	Few sources; simple terrain.
Refined	AERMOD	Appendix D	≤ 50 km	Regulatory Mesoscale + onsite (if available)	Simple terrain; okay for particle deposition assessment but not acid deposition assessments
	CALPUFF	Appendix D	≤ 200 km	Regulatory Mesoscale + onsite (if available)	Complex and simple terrain
Advanced	AERMOD	Written approval of Director before modelling; side by side comparison with Refined model required	≤ 50 km	Regulatory Mesoscale + onsite (if available)	Simple terrain; okay for particle deposition assessment but not acid deposition assessments
	CALPUFF	Written approval of Director before modelling; side by side comparison with Refined model required	≤ 200 km	Regulatory Mesoscale + onsite (if available)	Complex and simple terrain
Alternate	Other	Written approval of Director and AEP before modelling; side by side comparison with Refined model required		Regulatory Mesoscale + onsite (if available)	Open source; deprecated regulatory models are not allowed

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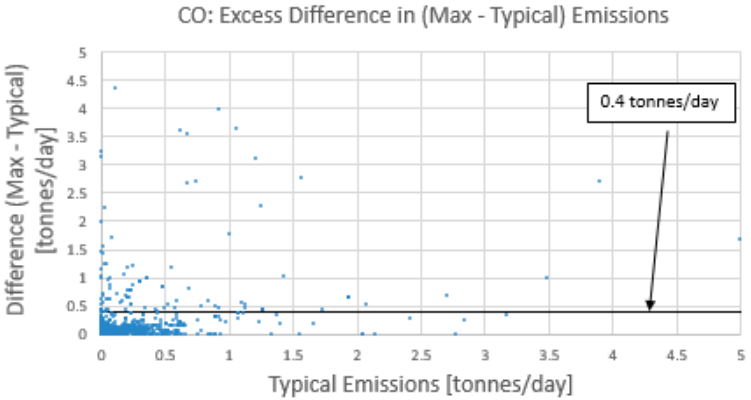
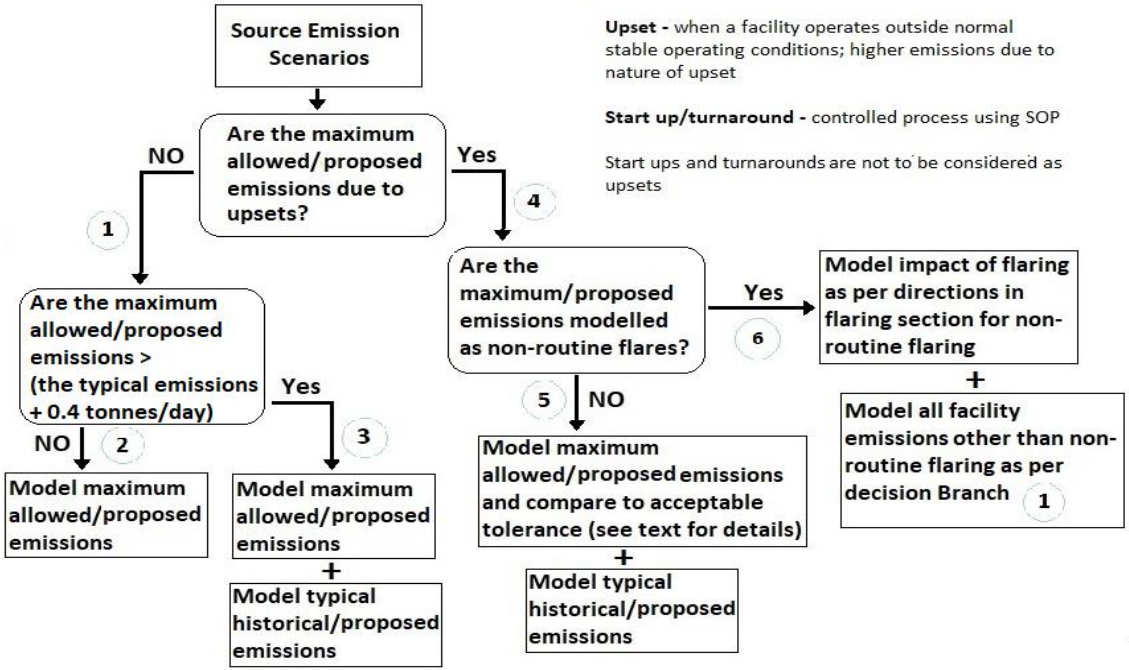
New
– estimated rates
Renewal/Amendment
– historical
Annual averages
– annual rates





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Modelling Approach

Source Types

De Minimis Sources may be excluded

- Identified according to AEIR reporting criteria
  - In total only a few percent of facility total for given substance
- Must consider nearby sensitive receptors

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Modelling Approach

Source Types

Merged Stack Sources

- EPA formulation (EPA 1992)
  - Similar stack parameters
  - Merged sources can be used for screening model
  - Must consider nearby sensitive receptors
  - Must consider downwash

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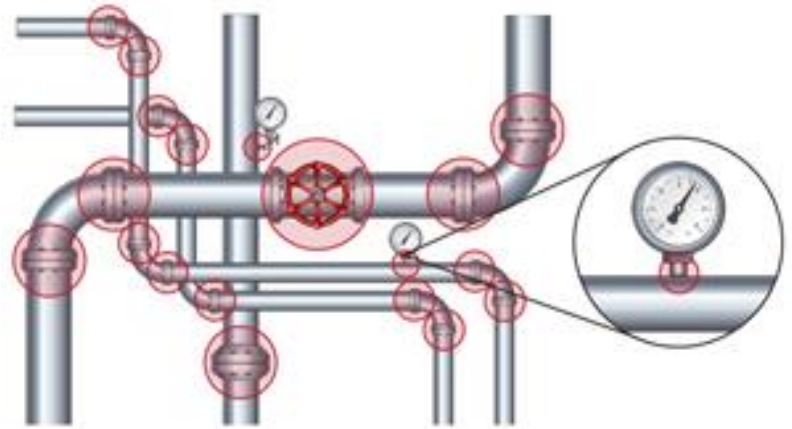
Modelling Approach

Source Types

Fugitive Emissions

- AP42
- CAPP recommended values



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Modelling Approach

Source Types

Flaring

- Use AER flaring tools to generate pseudo-parameters for all flare modelling
  - Continuous
    - only pseudo-parameters
  - Non-routine
    - AER risk-based approach

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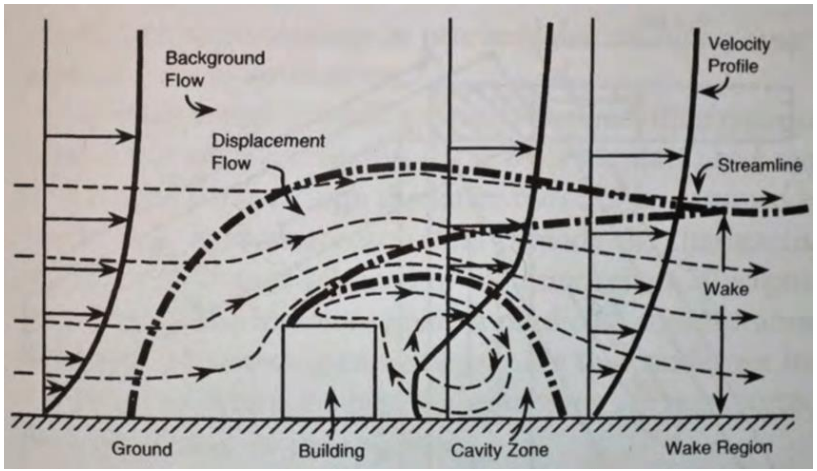

Modelling Approach

Source Types

Building Down Wash

Several formulations allowed

- Prime
- ISCST3 (under certain configurations)

Alternate

- ORD
- Prime2/AWMA

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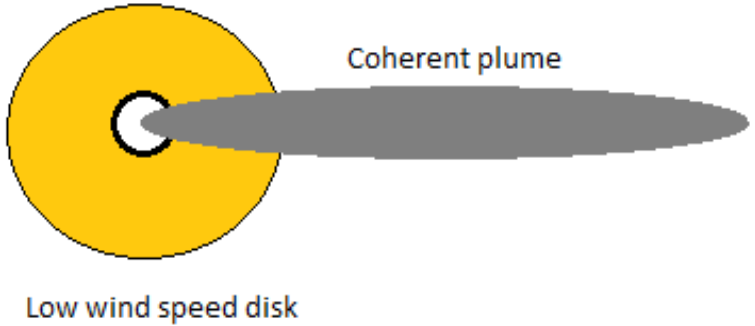

Modelling Approach

Source Types

Low-wind Options (AERMOD)

- Use EPA default option at moment
- If EPA sets new parameterization then use these

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Modelling Approach

Source Types

Particulate Emission (TSP) from stack surveys

- Distribute emissions per bin
- Aerodynamic profiling for correct transportation

Example:
Create the appropriate input to model TSP and $PM_{2.5}$ from a pulp and paper source that is emitting 10 g/s of TSP. From the AEIR Standard (Alberta Environment and Parks, 2018) a pulp and paper source has ($PM_{2.5}$/TSP) = 0.560 and (PM_{10}/TSP) = 0.737 (recall that PM_{10} is cumulative and includes the $PM_{2.5}$ mass fraction).

AERMOD Solution:

To set up AERMOD it is necessary to first define the mass fraction. For this problem a table of input values for particulate deposition modelling is as follows:

PM Species	Mean Particle Diameter (μm)	Mass Fraction*	Particle Density (g/cm^3)	Mass (g)
P1 (PM2.5)	0.625	0.1400	1	1.400
P2 (PM2.5)	0.875	0.1400	1	1.400
P3 (PM2.5)	1.125	0.1400	1	1.400
P4 (PM2.5)	1.875	0.1400	1	1.400
P5 (PM10)	4.250	0.0885	1	0.885
P6 (PM10)	8.000	0.0885	1	0.885
>PM10	20.000	0.2630	1	2.630

* The mass fraction is assumed to be distributed uniformly amongst the different diameter bins associated with a particular PM species.

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Modelling Approach

Baselines

Total Particulate Matter (TPM)

- Limited PM_{10} data
- Profiling using available data
- Not zero

General Guidance

- Clarity about what is in the modelling
- Clarity about what is missing – general guidance on selecting representative baseline

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Modelling Approach

Surface Characteristics

Revised Bowen Ratio, Albedo, and Surface Roughness

- 2015 Canadian Land Use
- NLCD equivalent
- Used in developing new meteorology

Appendix E AEP Recommended Default Surface Characteristics

Table E 1 **Surface Roughness Length (m) for Land Use by Season**

Canada 2015: Land Use Cover FGP Code[1]	NLCD 2016[2]	NLCD Code	Seasonal Surface Roughness			
			Winter	Spring	Summer	Fall
Water	Open Water	11	**0.001**	**0.001**	**0.001**	**0.001**
Snow and Ice	Perennial Ice/Snow	12	**0.002**	**0.002**	**0.002**	**0.002**
	Developed, Open Space	21	0.020	0.030	0.040	0.030
	Developed, Low Intensity	22	0.050	0.090	0.100	0.090
Urban	Developed, Medium Intensity	23	**0.200**	**0.300**	**0.300**	**0.300**
	Developed, High Intensity	24	0.700	0.700	0.700	0.700
	Barren Land (Rock/Sand/Clay) (Arid Region)	31	NA	0.050	0.050	0.050
⋮						
	Palustrine Aquatic Bed	98	0.050	0.050	0.050	0.050
	Estuarine Aquatic Bed	99	0.050	0.050	0.050	0.050

[1] Canada LUC 2015

[2] Table 6-5. Seasonal Values of Bowen Ratio for the NLCD 2001-2016

There are no arid areas in the province as per the NLCD definition.

Default surface values are indicated by the green shaded/bolded entries. Cream shaded boxes indicate interpolated values for this document.

Definition of Seasons:

"Spring" refers to periods when vegetation is emerging or partially green. This is a transitional situation that applies for 1–2 months after the last killing frost in spring.

"Summer" applies to the period when vegetation is lush and healthy, typical of midsummer, but also of other seasons where frost is less common.

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$$C_{sub\text{-}hour} = C_{hour} \times (\text{sub-hourly time/hour})^{-0.28}$$

$$= C_{hour} \times 1.21$$

Modelling Output

Hourly

- May exclude top 8 values (top 0.1%)

Super-Hourly

- Must include all hourly values
  - 8-hour average remove top value
  - 24-hour average and longer no removal allowed

Sub-Hourly

- Restricted to odour management AAAQGs
- 30 minute average period
- Must be based on include all hourly values
  - May exclude top 0.5% (based on Ontario guidance) – exclude top 44 "sub-hourly" values based on hourly data

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Model Output

Chemistry

NO_2/NO_x

$$\sum_{i=1}^{N}[NO_2]_{predicted\ hourly,i} = [O_3]_{ambient\ hourly} + \sum_{i=1}^{N} ISR_i * [NO_x]_{predicted\ hourly,i}, \quad (4c)$$

which can be further broken down into project and non-project source contributions:

$$\sum_{i=1}^{N}[NO_2]_{predicted\ hourly,i} = [O_3]_{ambient\ hourly} + \sum_{i=1}^{n} ISR_i * [NO_x]_{predicted\ hourly\ project\ sources,i} +$$

$$\sum_{i=N-n}^{N} ISR_i * [NO_x]_{predicted\ hourly\ non-project\ sources,i}. \quad (4d)$$

1. Total Conversion Method (always)
2. PVMRM/OLM (AERMOD)/ OLM: use in-stack ratios if available

Default ISR_i = 0.2

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Model Output

Chemistry

NO_2/NO_x

3. RIVAD/ISORROPIA (CALPUFF): Use Alberta default NH_3 and H_2O_2 values if no better available
4. ARM (AERMOD and CALPUFF): Use downwind monitoring ratios

   Default value = 0.7

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Model Output

Chemistry

NO_2/NO_x

5. ARM2 (AERMOD and CALPUFF):

   Use current EPA methodology

   if NO_2 (project, total) <= 200 ppb use as is

   if NO_2 (project, total) > 200 ppb modify based on ISR.

   If all project ISR < = 0.2 then use default

   If any project ISR > 0.2 then use stack ISRs

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Model Output

Chemistry

NO_2/NO_x

In Stack Ratios (ISRs):

1. Stack testing (AEIR)
2. Manufacturer's data
3. EPA list of acceptable ISRs
4. Default values if no better information available:

    Project ISRs = 0.2

    Non-project = 0.2

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Model Output

Other chemistry

TRS

Reported as TRS, use as is

Reported as mix (e.g., H2S, CS2, etc.), then form simple mass sum

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Model Output

Other chemistry

SO_2, SO_4, etc. (acid deposition)

- Use CALPUFF or other AEP recommended model (not AERMOD)
- Use RIVAD/ISORROPIA chemistry (CALPUFF)
  - Use Alberta default NH_3 and H_2O_2 values if no better available

Appendix G AEP Recommended NH_3 and H_2O_2 Levels

For CALPUFF deposition and secondary particulate matter studies, it is important to set representative NH_3 and H_2O_2 levels. If onsite NH_3 and H_2O_2 data is available it must be used, particularly in areas where there are known sources of NH_3 (e.g., agricultural operations), otherwise use the default values.

Table G 1 **Recommended Default NH_3 Monthly Levels**

NH_3 [ppb]*											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.5	1.5	1.5	2.5	2.8	3.2	3.2	3.0	2.5	2.0	1.5	1.5

* Adapted from Warner et al., 2017 assuming Alberta's seasonal variability.

Table G 2 **H_2O_2 Hourly Levels by Season**

H_2O_2 [ppb]**						
	Urban/Industrial			Rural		
Hour	Winter	Summer	Spring/Fall	Winter	Summer	Spring/Fall
0:00	0.30	0.50	0.40	0.54	0.43	0.48
1:00	0.35	0.60	0.48	0.56	0.41	0.49
2:00	0.40	0.70	0.55	0.59	0.39	0.49
⋮						

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Model Output

Acid Deposition

When required:

1. The proponent's combined emissions of SO_2, NO_x, and NH_3 are greater than 0.175 t/d of H^+ equivalent, i.e.,

   Total H^+ equivalent (t/d) =
   $2*(SO_2\ t/d)/(64)+1*(NO_x t/d)/(46)+1*(NH_3\ t/d)/(17)$, (5)

   or

2. There is evidence that regional soil and surface water is more sensitive to acidification than is estimated in the provincial framework, or

3. There is existing deposition and/or acidification impact monitoring that indicates a potential concern if acid deposition increases.

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Model Output

Acid Deposition

- Use Acid Deposition Management Framework (ADMF) to determine if critical load is exceeded
- Base Cation Deposition: Incorporated into ADMF already – add additional deposition in areas of heavy crustal disturbance
- Meteorology: Use median average deposition value based on five year regulatory data set
- Emissions: Annual average

Meteorology: Update 2021.

Alberta's Meteorology: Update 2021

Current Meteorology

2002 – 2006 MM5

12 km resolution

30 layers

Complete province

Convenient extraction tool (MMEU)

500 GB

Why new meteorology?

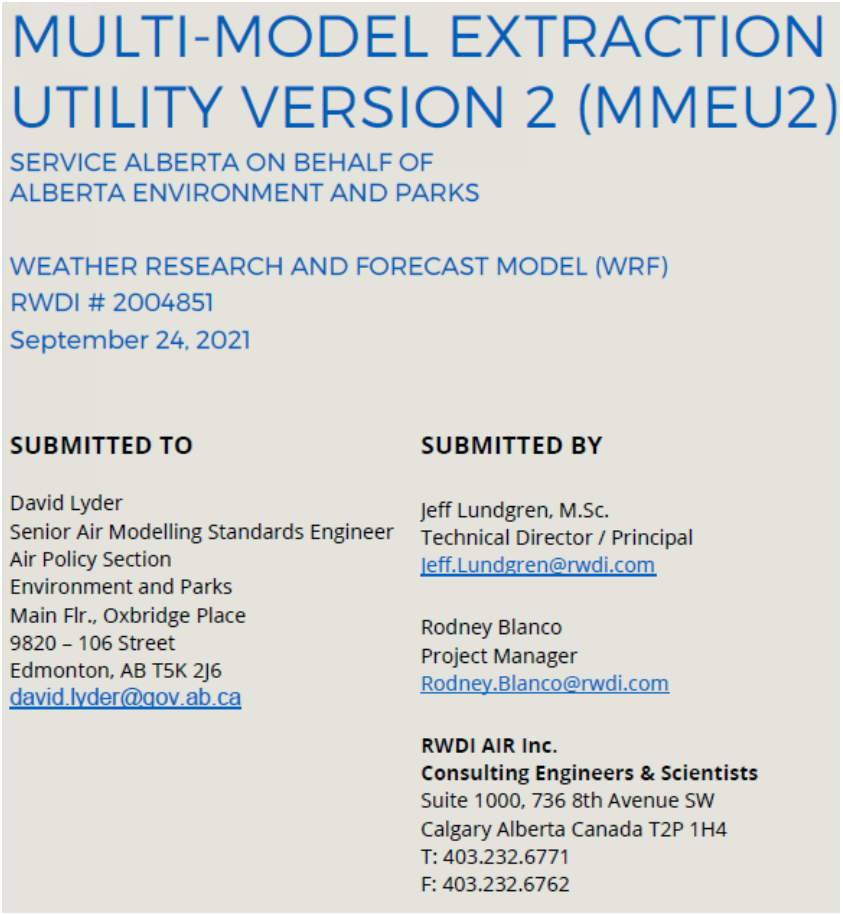
MM5 is dated – no longer supported

Weather Research Model (WRF) has improved physics – state-of-science mesoscale weather model

More ground data available to develop model

Alberta's Meteorology: Update 2021

New Meteorology



MULTI-MODEL EXTRACTION UTILITY VERSION 2 (MMEU2)

SERVICE ALBERTA ON BEHALF OF
ALBERTA ENVIRONMENT AND PARKS

WEATHER RESEARCH AND FORECAST MODEL (WRF)
RWDI # 2004851
September 24, 2021

SUBMITTED TO

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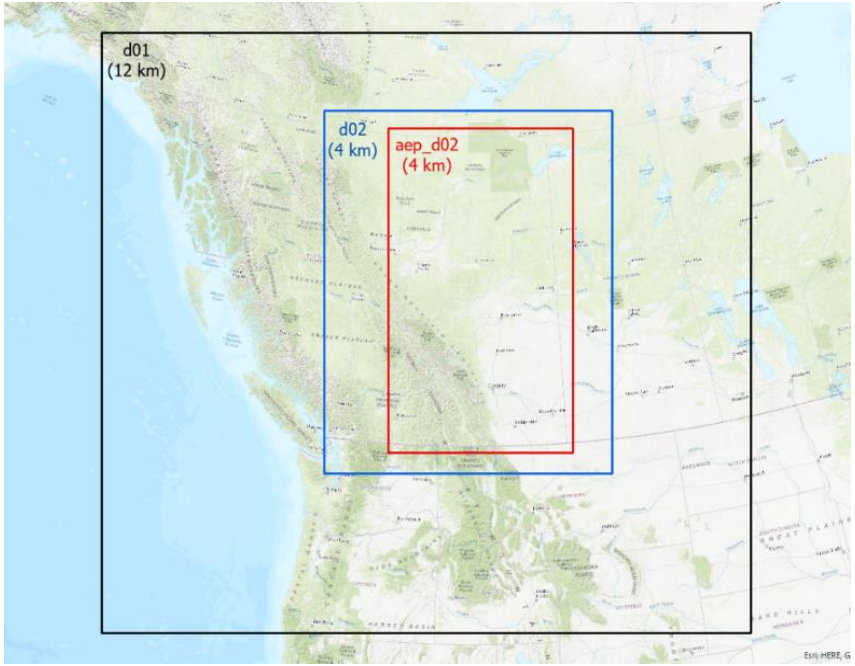
New Meteorology

- WRF V4.2.1, WPS 4.2
- 0.25^{o} ERA5 outer nest
- 12 km/4km inner nests
- 39 layers up to 100 mb



Alberta's Meteorology: Update 2021

New Meteorology

- Physics built on previous CMAQ studies (AEP 2018)
- Improved boundary conditions
- Increased ground data for observational nudging (300+ stations)

Table 2: MMEU2 WRF Configuration

WRF Process	MEUE2 WRF Configuration
Model Version	WRF 4.2.1, WPS 4.2*
Grid Nesting	12/km run together with 1-way feedback*
Longwave Radiation	RRTMG
Shortwave Radiation	RRTMG
Land Surface Model (LSM)	Noah
Planetary Boundary Layer (PBL) scheme	MYJ
Explicit Moisture Scheme	WSM6
Cumulus Parametrization Scheme	Grell-Freitas on 12/4km
Analysis Nudging	Nudging applied to winds, temperature and moisture every 3 hours, 12km only*
Analysis Nudging Wind Coefficient	3x10-4
Analysis Nudging Temp Coefficient	3x10-4
Analysis Nudging Moisture Coefficient	3x10-4
IC/BC + Analysis nudging dataset	ERA5*
Observation Nudging	Nudging applied to both surface wind and temperature for 4 km domains only
Observation Nudging Dataset	MADIS plus ACIS*
Observation Nudging Wind Coefficient	3x10-4
Observation Nudging Temp Coefficient	1x10-4
Observation Nudging Moisture Coefficient	None

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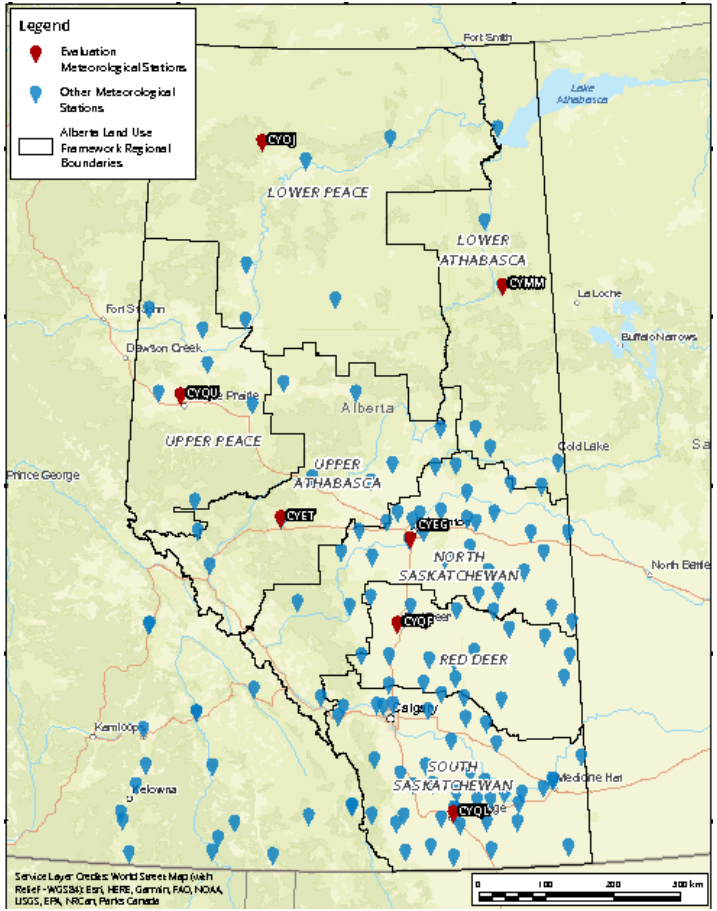
Model Validation

- One MADIS station held back per land use region
- Performance based on bias, absolute error and/or RMSE: 2-m temperature, wind speed/direction, vapor mixing ratio
- January, April, July, October for all years



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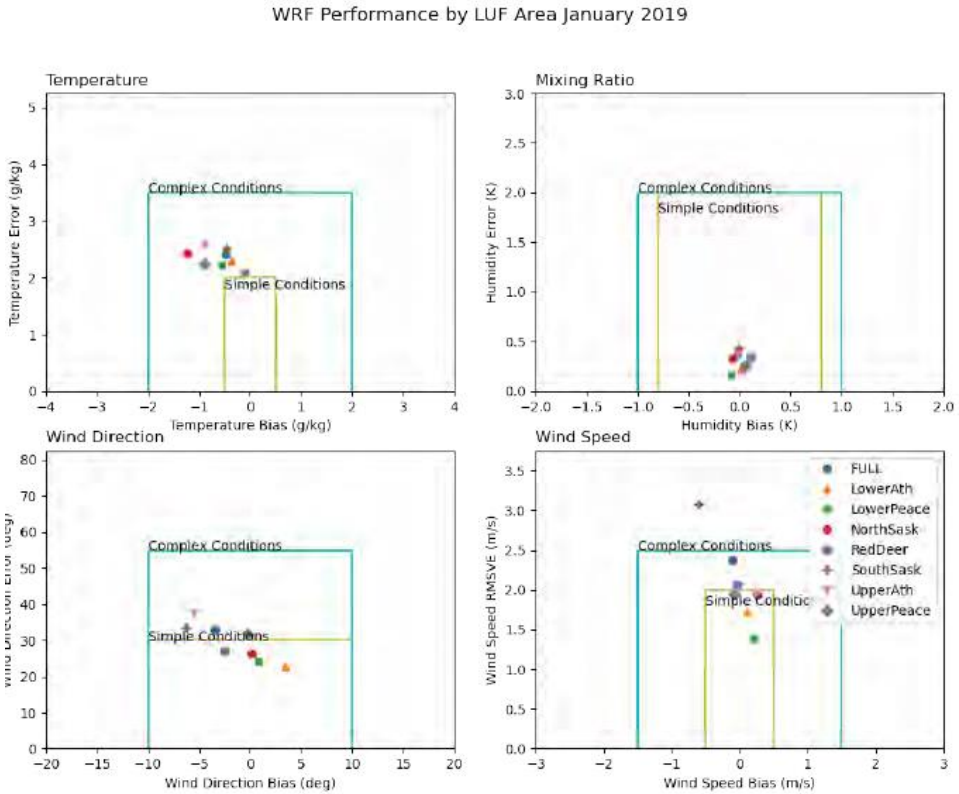

Model Validation

- Soccer plot graphical assessment of error and bias
- For the most part model performs well and meets simple and complex terrain performance criteria

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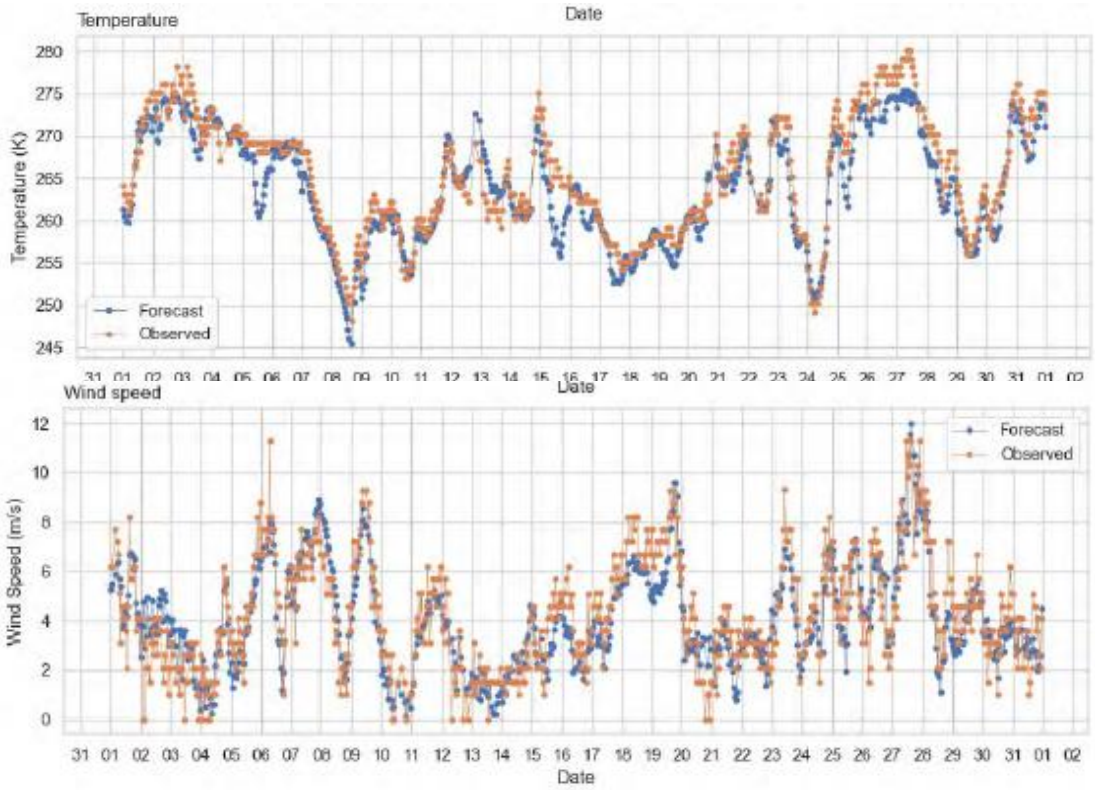
Model Validation

- Time series also indicated very good model performance



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MMEU2

- Very similar to previous MMEU
- User manual will be available

MULTI-MODEL EXTRACTION UTILITY 2 (MMEU2) & 2015-2019 ALBERTA METEOROLOGICAL DATA SET USER'S GUIDE

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MMEU2

Using the tool

- Disclaimer

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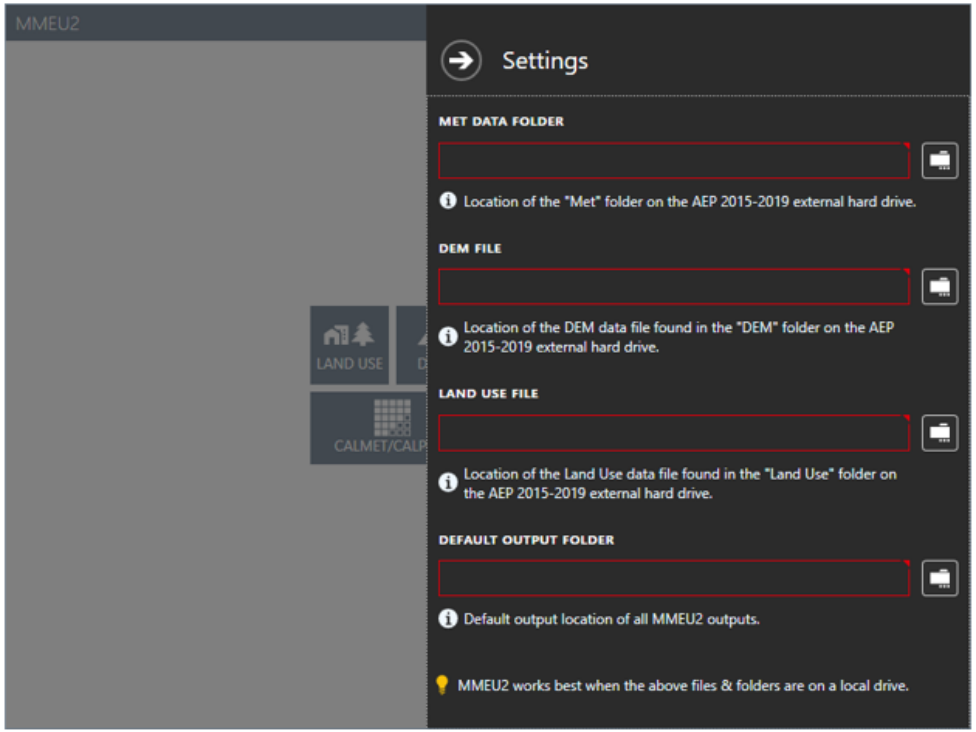
MMEU2

Using the tool

- Pathway
  - Met data
  - DEM
  - Land Use data
  - Output



The directories specified in the Settings dialog can be modified at any time by selecting the Settings Gear located in the upper right-hand corner of the application.

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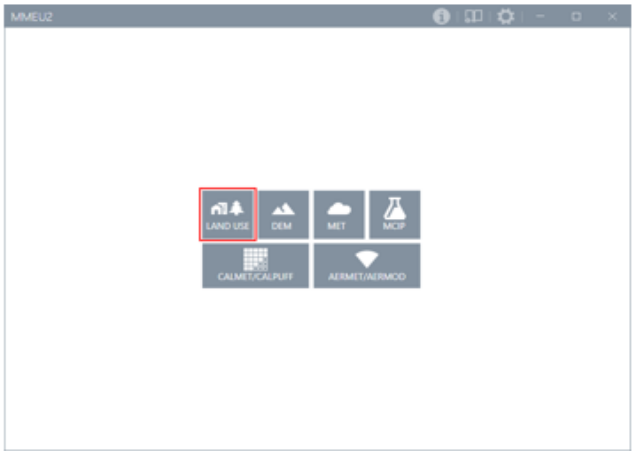
MMEU2

Using the tool

- Land Use data
- Default – native resolution (30 m); can use coarser resolution



The spatial extent screen is used to specify the extents of the region.

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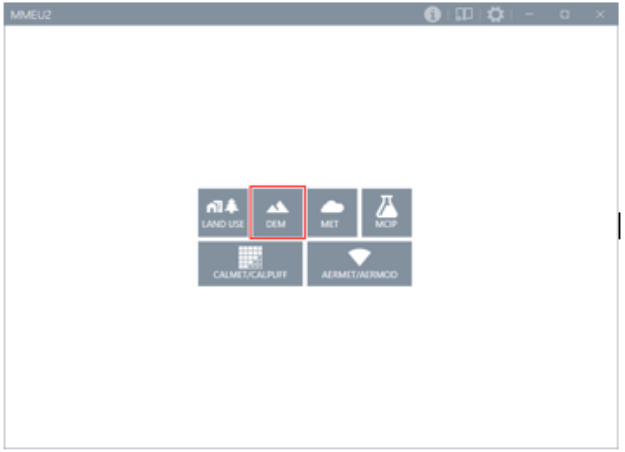
MMEU2

Using the tool

- DEM data
- Default – native resolution (25 m)
- Can use coarser resolution: different interpolation schemes



The spatial extent screen is used to specify the extents of the region.

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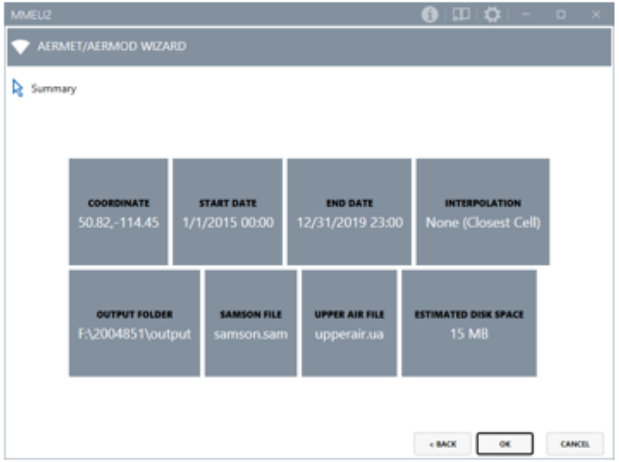
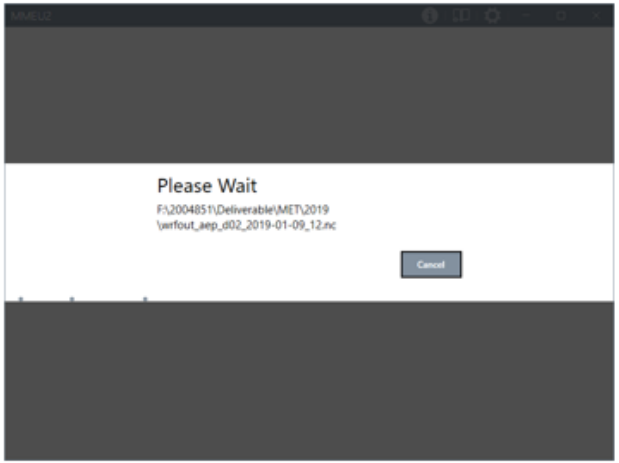
MMEU2

Using the tool

- AERMET ready
- SAMSON, RAOBS, Stage 1, 2 and 3
- Still have to do visualization check of upstream land use zones (not AERMAP)





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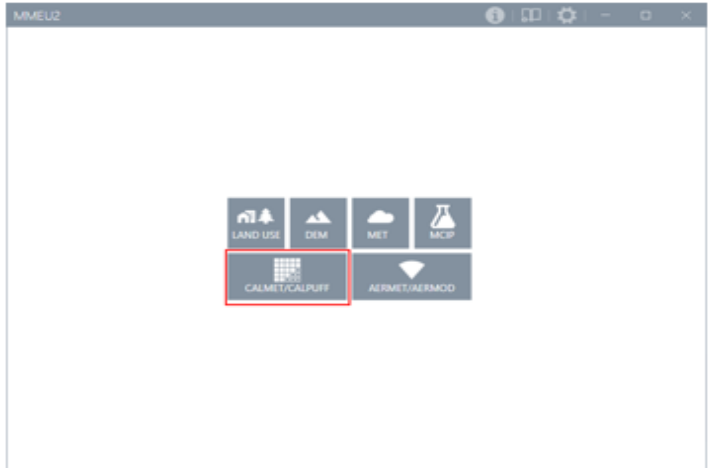
MMEU2

Using the tool

- GEO.DAT
- CALMET/CALPUFF ready (.INP files)



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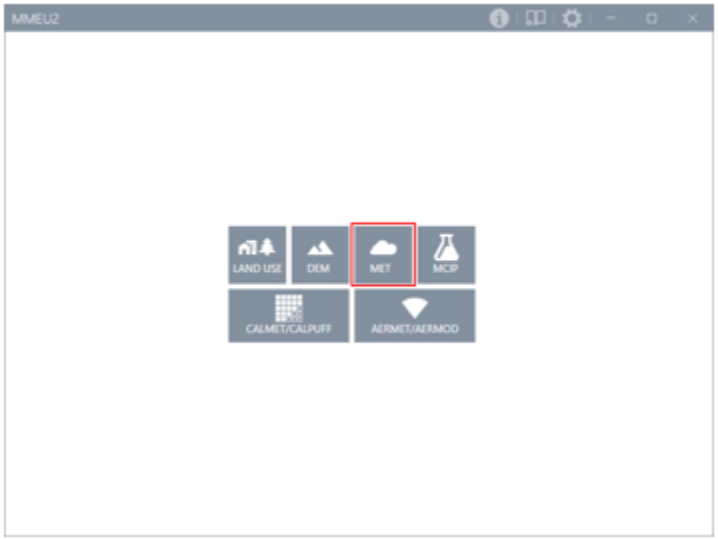
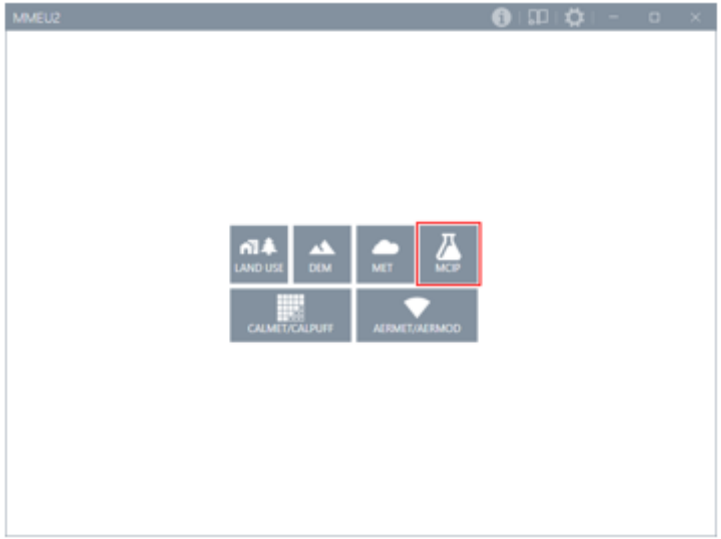
MMEU2

Using the tool

- Other
  - WRF
  - MCIP





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Cost

Comparable to cost of current MM5 data (~$500)

- confirmed at purchase

Large data set (10 TB)

- be prepared to receive it

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Questions?