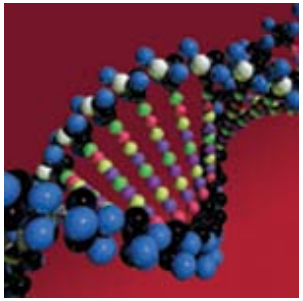
A New Direct MM5/WRF Meteorological Interface Program for CALPUFF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AWMA Guideline on Air Quality Models:
Next Generation of Models, Raleigh, NC
October 28, 2009

ENVIRON

Introduction

- EPA & FLMs have considered a direct interface between prognostic meteorological models and CALPUFF for several years
  - First discussed at EPA's 8th Conference on Air Quality Modeling in September 2005
  - Adopt for regulatory CALPUFF applications
  - Bring a higher level of consistency to the review process
- Design features:
  - A single-purpose processors in the style of Models-3 MCIP
    - Minimizes alternations to prognostic meteorological fields
  - Statistical and graphical performance analysis capability
    - Evaluate MM5, WRF, and CALPUFF-ready met fields

Introduction

- In 2007-08 EPA developed a prototype MM5-CALPUFF re-reformatting tool
  - Based on ENVIRON's MM5CAMx and EPA's MCIP
- In 2008-09 EPA & FLMs funded ENVIRON to review and update the prototype
  - Mesoscale Model InterFace (MMIF) version 1.0
- EPA is conducting comprehensive testing of MMIF + CALPUFF
  - Preparing for regulatory review and public distribution
  - Statistical/graphical performance package is being developed
    - Contract with Alpine Geophysics to be completed by end of 2009

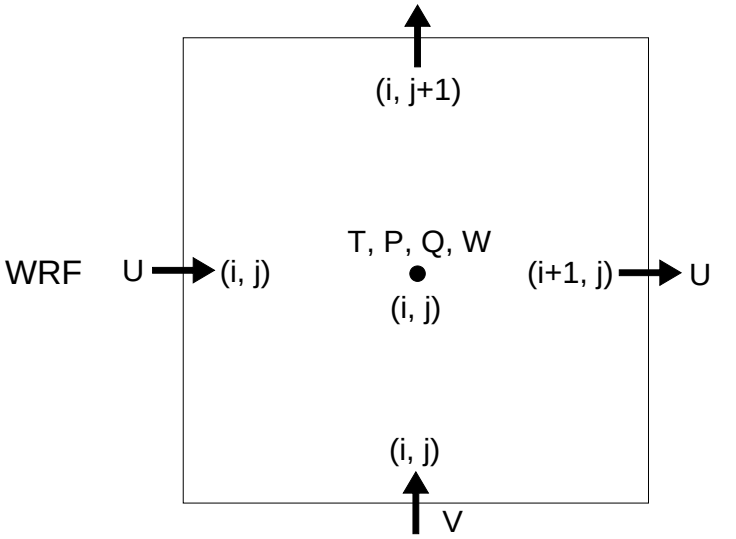
MMIF v1.0

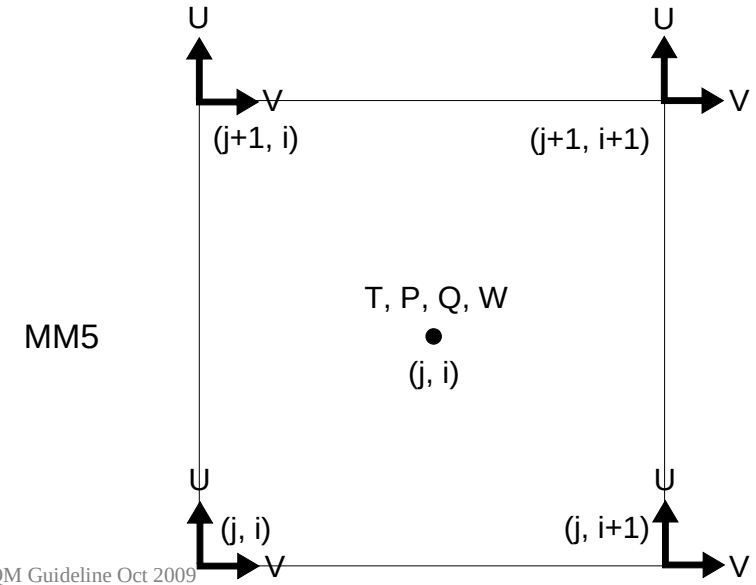
- From prototype to MMIF
  - Review prototype code, de-bug, and update as necessary
  - Re-write entirely in F90 with dynamic memory
  - Expand to include WRF/ARW
  - Develop to compile and run on Linux/Unix and Windows
  - Organize into modular structure with in-code documentation:
    - Facilitate regulatory review
    - Allow for future upgrades
  - Conduct functional testing of MMIF
- Overall Function
  - Reads raw output files from MM5 v3 or WRF/ARW v2/3
  - Diagnoses parameters not directly output by MM5/WRF
  - Optionally re-diagnoses or passes through PBL heights

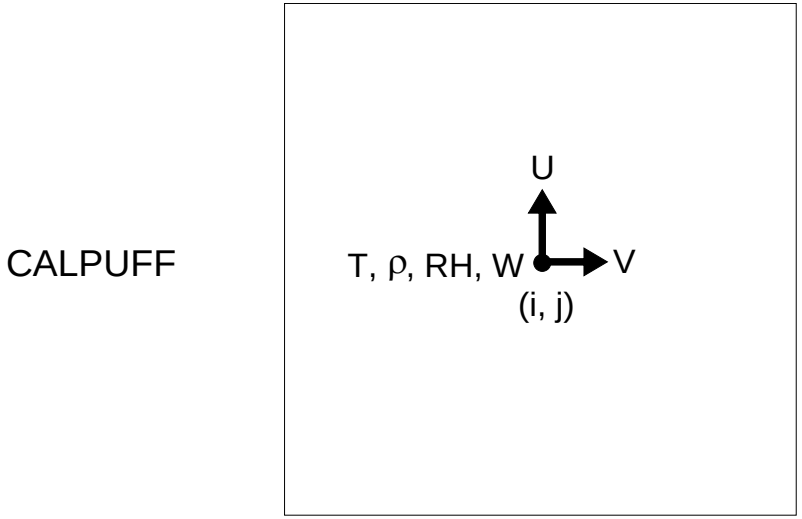
MMIF v1.0

- Overall Function (continued)
  - Optionally processes data on a sub-set of met output grid
    - Horizontal: simple window of the full domain
    - Vertical: layer mass-weighted aggregation
  - Generates a CALPUFF-ready input file (CALMET.DAT)
    - Output format equivalent to "NOOBS" and "CALGRID" options:
    - Meteorological model pass-through
    - 3-D winds and temperature fields
  - Optionally writes projection/grid data for CALPUFF control file
- MMIF does not:
  - Generate cloud information
  - Interpolate to different projections or grid resolutions

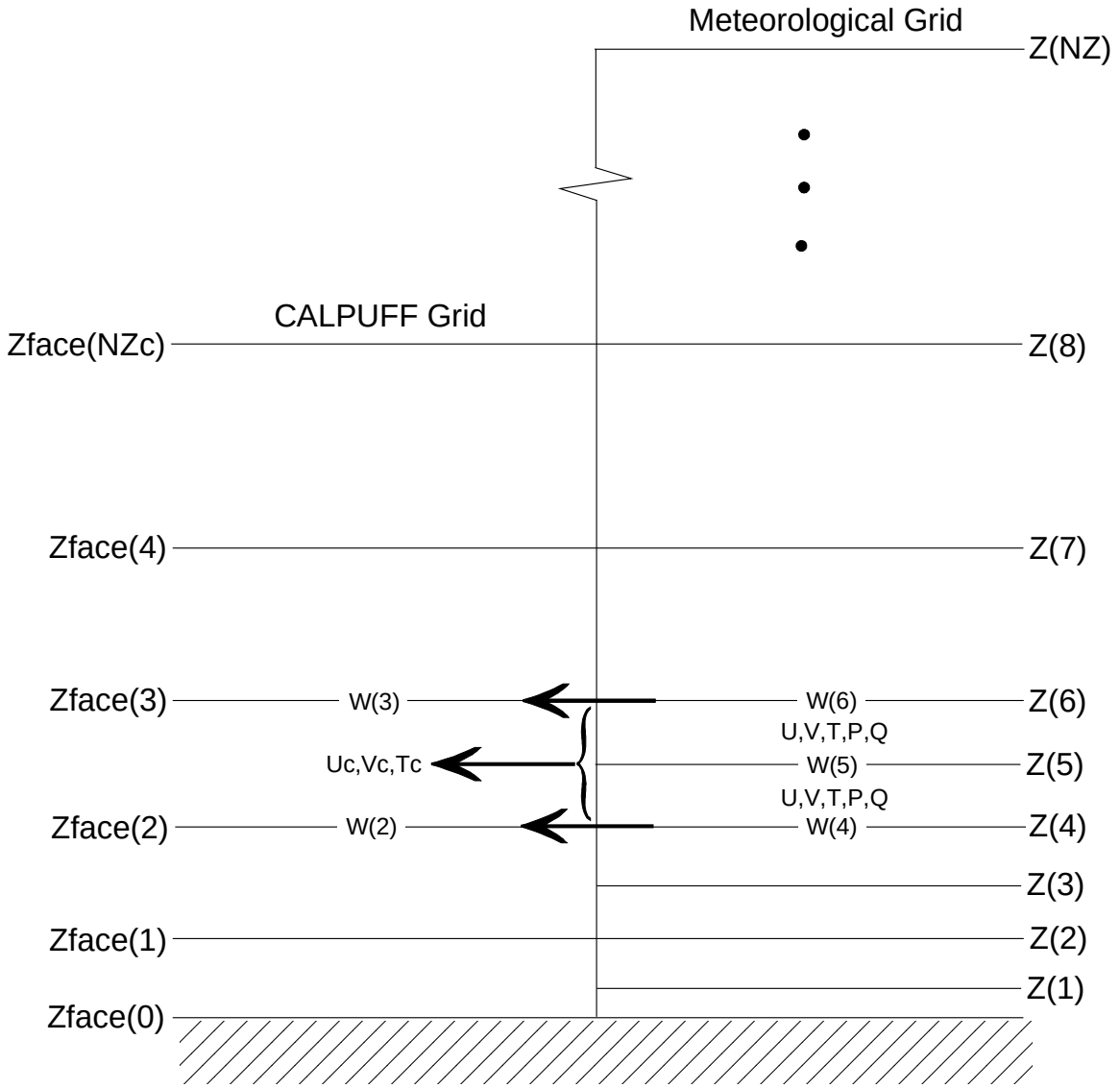
Horizontal Grid Translation







Vertical Grid Aggregation



Surface Characterization

- MMIF outputs four static 2-D surface fields
  - Landuse (ILANDU) code and topographic elevation (ELEV) are passed through
  - Surface roughness (Z0) and leaf area index (XLAI) are set according to ILANDU
- MMIF assumes MM5/WRF use standard USGS 24-category landcover
  - Any other dataset stops MMIF with an error
  - Z0 and XLAI are set according to USFS BlueSky/RAINS MM52GEO program
    - Seasonal dependence (winter vs. summer)
    - Equivalent to MM5 and WRF 24-category default

Surface (10-m) Parameters

- MMIF outputs ten time-variant 2-D surface fields
  - Three MM5/WRF surface variables are passed through:
    - Friction velocity scale (USTAR), surface temperature (TEMPK), solar flux (QSW)
  - Three variables are calculated via Louis (1979) surface layer parameterization:
    - 10-m temperature (T-LEV), Monin-Obukhov length (EL), convective velocity scale (WSTAR)
    - 10-m winds (U-LEV, V-LEV) if not available from MM5
  - Density (RHO) and relative humidity (RH) are calculated from MM5/WRF layer-1 temperature, pressure and humidity
  - Rainfall rate (RMM) is passed through as sum of MM5/WRF resolved and sub-grid precipitation
  - Precipitation code (IPCODE) is set according to temperature above (liquid) or below freezing (snow)

PG Stability Class

- CALMET calculates PG stability using Turner (1970) method, 2 ways:
  - Observation-based (ceiling height/cloud cover from surface obs)
  - "NOOBS" method (ceiling height/cloud cover diagnosed from MM5 data)
- MMIF provides 2 PG options that don't need clouds:
  - SRDT method, Supplement C to the Guideline on Air Quality Models (EPA, 1993)
    - Based on wind speed, solar radiation, and "Delta-T"
    - From the Meteorological Processor for Regulatory Models (MPRM)
  - Golder (1972) method
    - Function of Monin-Obukhov length and surface roughness
    - From the AERMOD LTOPG subroutine

PBL Depth

- MMIF provides two PBL options
  - Pass through from MM5/WRF output
  - Re-diagnosis:
    - Bulk Richardson approach of Vogelezang and Holtslag (1996) using the Louis (1979) surface parameters
    - Methodology of Gryning and Batchvarova (2003) reduces critical Richardson number for over-water PBL height
    - Based on MCIP "PBLSETUP" routine

MMIF Run Control

- Simple text file
  - Easy to script, limited options

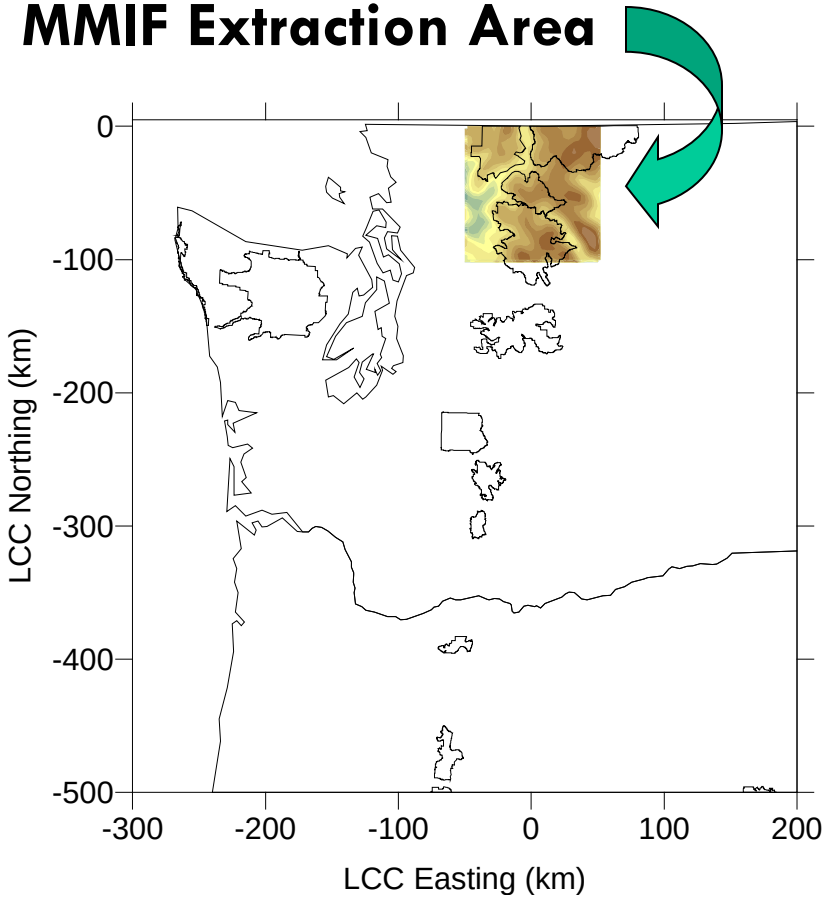
```
MM5 or WRF?          |MM5
Start Extracting     |2006 05 29 01
Stop  Extracting     |2006 05 30 00
Output Time Zone     |-6
P-G Calc Method      |1
Re-calc PBL Depth?   |F
Min, Max PBL Depth   |50.0 3000.0
I-range to Extract   |0 0
J-range to Extract   |0 0
Num Output Layers    |21
Layer Mapping        |1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,19,21,23,25
Useful Info File     |test_mm5.info.txt
Output Filename      |test_mm5.met
Num MM5/WRF Files    |2
/dquad9c/aacog/mm5/2006mm5_4km.run4/2006-05-28/MMOUT_DOMAIN4_01
/dquad9c/aacog/mm5/2006mm5_4km.run4/2006-05-28/MMOUT_DOMAIN4_02
```

MMIF Functional Testing

- 3 datasets on various Lambert grids:
  - MM5 version 3.6.3: 4 km domain over WA, OR, and ID
    - January 1, 2005
  - WRF version 2.2: 10 km domain over the northern half of AK
    - July 12, 2004
  - WRF version 3.0.1.1: 0.6 km domain over eastern WY
    - April 25, 1999
- Tested/compared on both Linux and Windows
  - Compared to CALMM5/CALWRF + CALMET (NOOBS) where possible

MM5 over Northern Washington Cascades

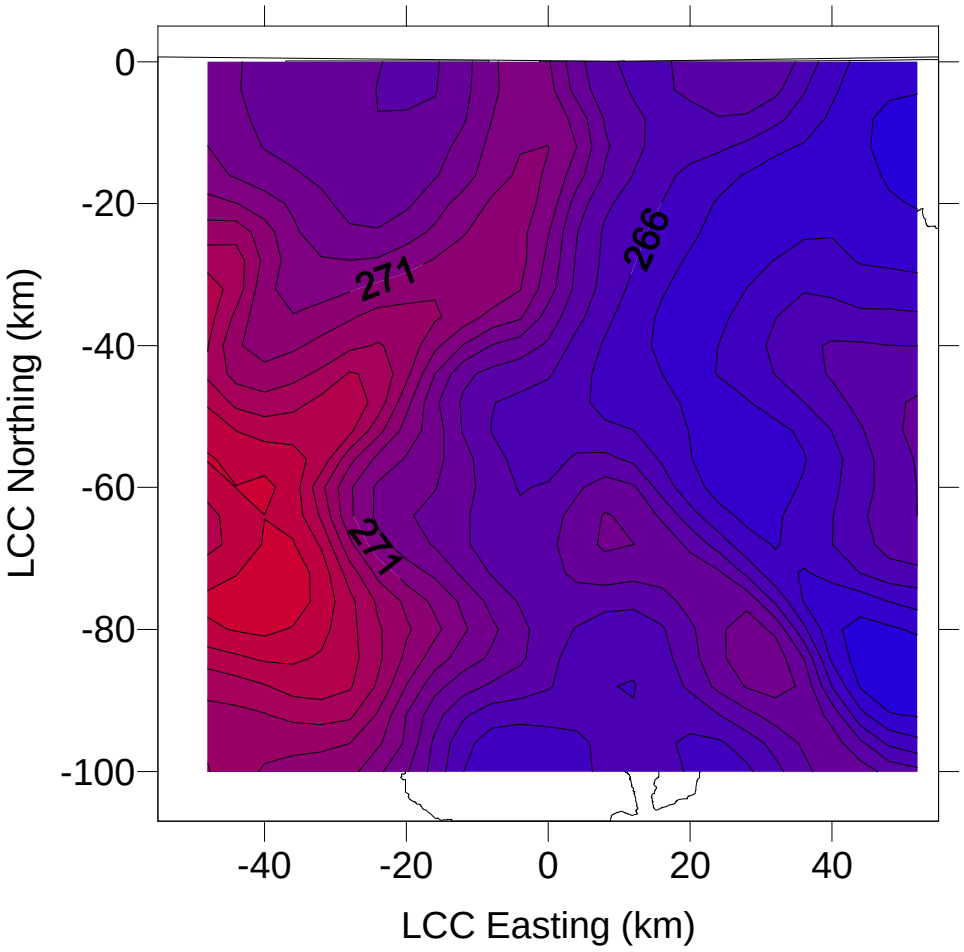
MMIF Extraction Area



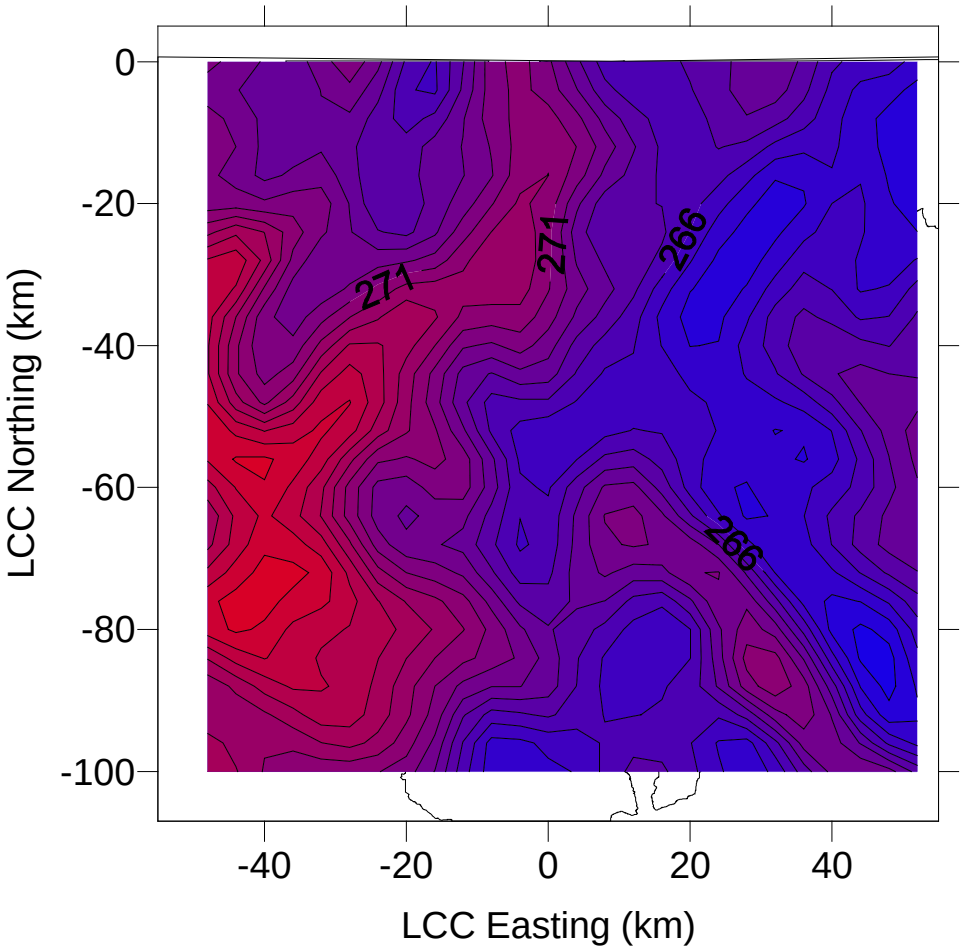
MM5 Layers (partial)	MM5 Half-Sigma Level	MMIF ZFACE (m)
23	.5800	3874
22	.6200	
21	.6600	
20	.6950	
19	.7250	2369
18	.7550	
17	.7850	
16	.8150	
15	.8450	1317
14	.8700	
13	.8900	
12	.9050	753
11	.9150	
10	.9250	
9	.9350	
8	.9450	445
7	.9550	
6	.9650	294
5	.9750	
4	.9825	146
3	.9875	109
2	.9925	73
1	.9975	20

MM5 over Northern Washington Cascades

CALMET 10-m Temp

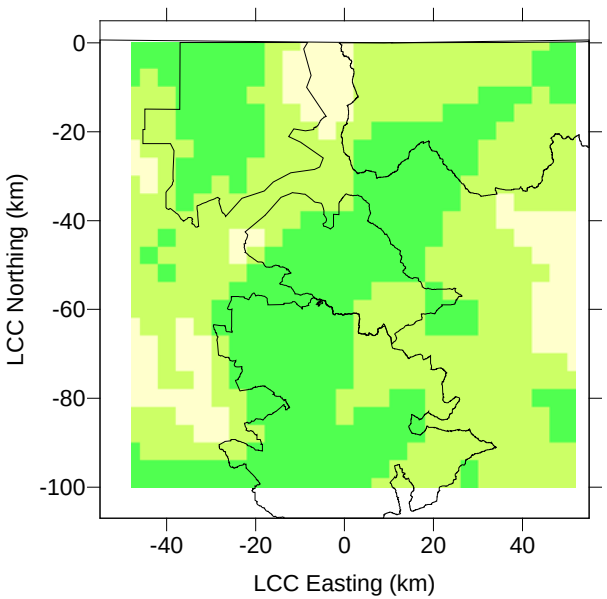


MMIF 10-m Temp



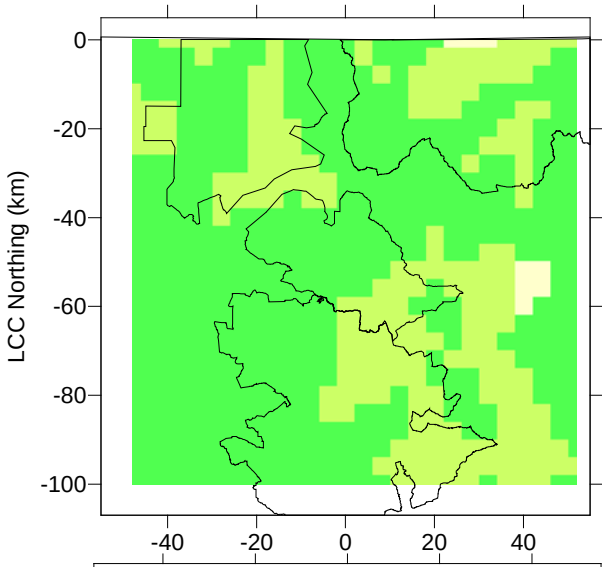
MM5 over Northern Washington Cascades

CALMET PG

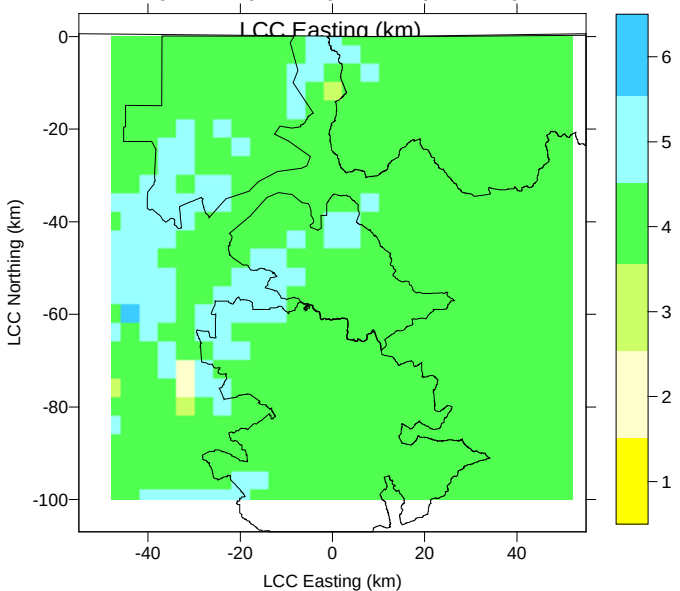


MMIF PG

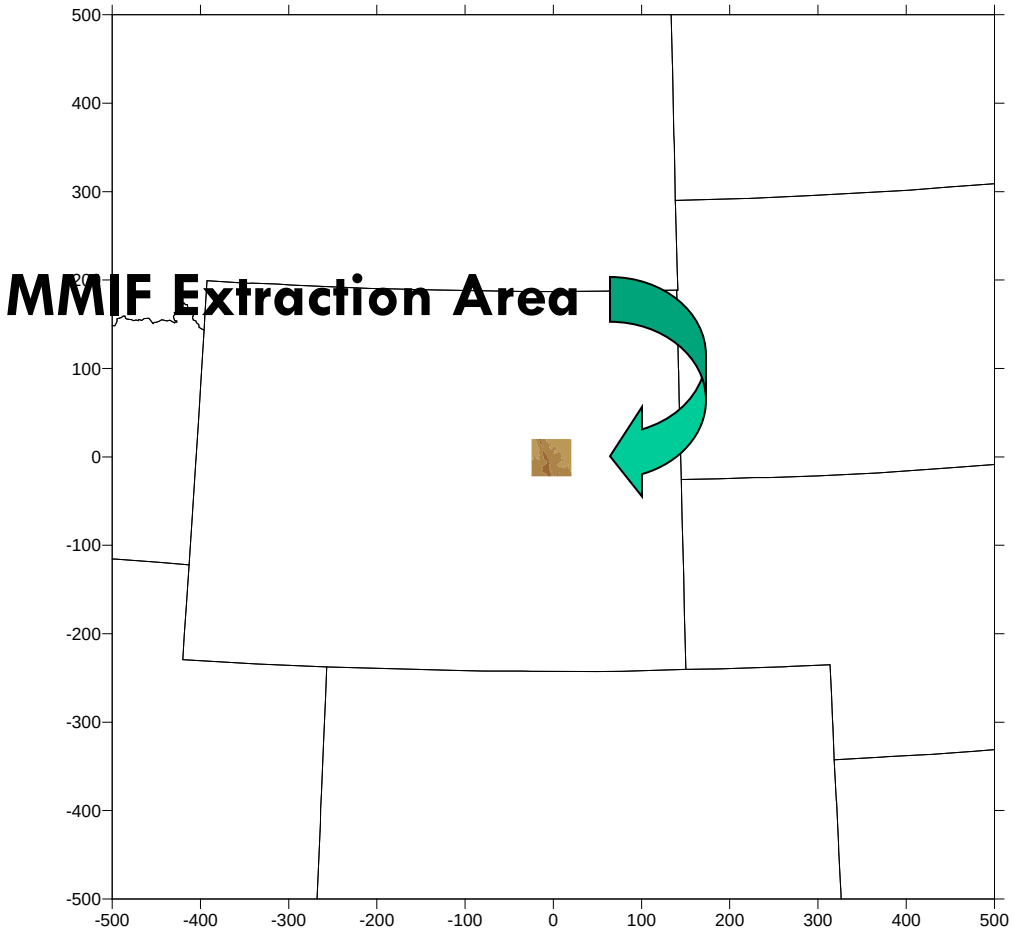
SRDT



LTOPG



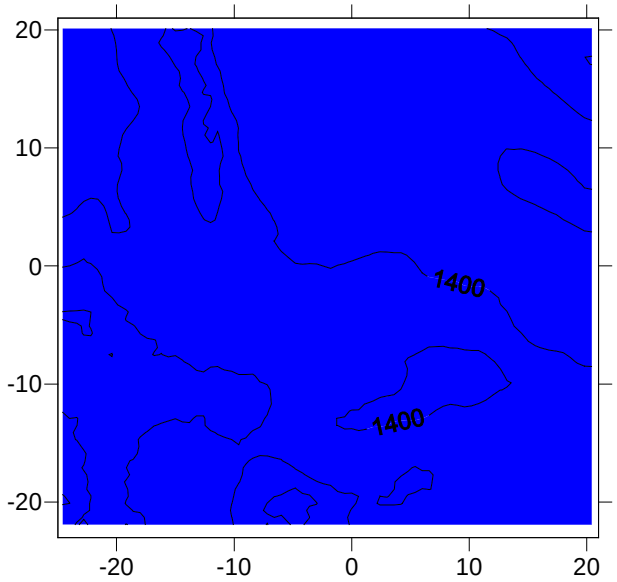
WRFv3 over Eastern Wyoming



WRF Layer (partial)	WRF Half-Sigma Level	MMIF ZFACE (m)
17	0.5730	4363
16	0.6175	
15	0.6595	3334
14	0.6990	
13	0.7355	
12	0.7695	2155
11	0.8010	
10	0.8300	1557
9	0.8565	
8	0.8805	1082
7	0.9025	
6	0.9230	706
5	0.9415	
4	0.9580	401
3	0.9730	271
2	0.9865	159
1	0.9965	55
		20

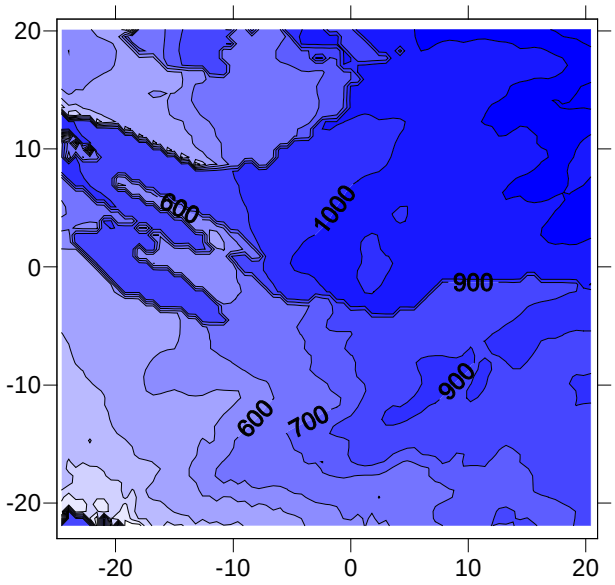
WRFv3 over Eastern Wyoming

CALMET PBL

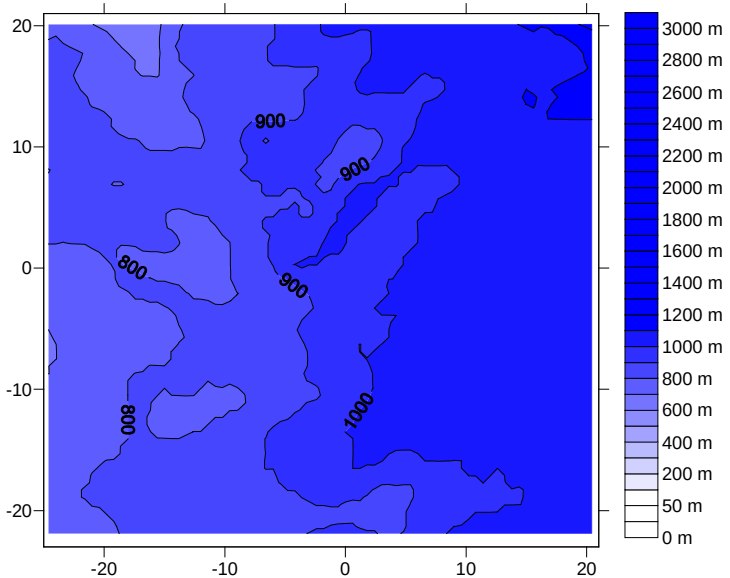


MMIF PBL

Pass-Through



Re-diagnosed



Summary

- Functional testing with MMIF
  - Consistent results between Linux and Windows
  - Consistent results for winds between MMIF and CALMET
  - Similar results for temperature and precipitation between MMIF and CALMET
  - Different results for diagnosed values between MMIF and CALMET
    - PG stability
    - PBL depth

Phase II - MMIFstat

- The MMIFstat program performs statistical analysis on the MMIF output files files and enables the MMIF user to assess the fidelity of the meteorological files and the suitability of the use of the files for subsequent air quality modeling.
- As time more MM5/WRF simulations become available the user will have the ability to use choose the best performing meteorological model simulation on an application specific basis.

MMIFstat Formulation

- The MMIFstat package and this documentation was developed in part from ENVIRON International Corporation (ENVIRON) METSTAT program. Key features of this package are:
  - Ability to quickly and efficiently evaluate surface meteorological parameters;
  - Ability to use readily available surface observation files;
  - Ability to select a subset of observations for analysis;
  - Applicability on either Linux/Unix or Windows platforms;
  - A simple text-based user interface "control" file structured like the MMIF file;
  - Ability to produce statistical file easily displayed in common CSV format;
  - Dynamic memory allocation to remove grid limits from application;

Statistical Benchmarks

- Emery et al. (2001) carefully considered the appropriateness and adequacy of the proposed benchmarks based upon the results of MM5 simulations performed and reported in that study. Based upon these considerations, the final daily proposed benchmarks are given below:

Wind Speed	RMSE:	$\leq$ 2 m/s
	Bias:	$\leq \pm$0.5 m/s
	IOA:	$\geq$ 0.6
Wind Direction	Gross Error:	$\leq$ 30 deg
	Bias:	$\leq \pm$10 deg
Temperature	Gross Error:	$\leq$ 2 K
	Bias:	$\leq \pm$0.5 K
	IOA	$\geq$ 0.8

MMIFstat Demonstration

Acknowledgement

- The MMIF and MMIFstat project were jointly funded by:
  - Environmental Protection Agency;
  - Fish and Wildlife Service;
  - Forest Service; and
  - National Park Service

- Questions…