Mesoscale Model Interface Program (MMIF) Overview and Summary of Testing

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10th Conference on Air Quality Modeling
EPA-Research Triangle Park, NC Campus
March 13-15, 2012

Outline

- Discuss the state-of-the practice of the use of prognostic and diagnostic meteorological data since publication of IWAQM Phase 2 recommendations
- Introduce design features elements of MMIF software
- Discuss testing procedures
- Introduce supporting software
- Next steps

IWAQM Phase 2

- The control of the CALMET options requires expert understanding of mesoscale and microscale meteorological effects (such as terrain slope flows) on meteorological conditions, and finesse to adjust the available processing controls within CALMET to develop the desired effects.
- The IWAQM does not anticipate a lessening in this required expertise in the future. Developing three-dimensional time varying fields of meteorological conditions is a demanding task, which can not be left to unskilled or inexperienced staff.

IWAQM Phase 2 – cont'd

- Developing CALMET meteorological fields is considered a difficult task just managing the sheer volume of input and output data of CALMET, and excellent computer skills are needed to manage the operation of the various processors to CALMET.
- The software was not written to accept a variety of input data formats. The software was developed with the assumption that the user is capable of screening the data for anomalous values. It was assumed that if the data are not in the required format, the user has the programming skills to write special programs to translate the data format to the format required.

The Current State of Practice

- Graphical User Interfaces (GUI's)
  - Considerable resources dedicated by Earth Tech, TRC, Lakes, Trinity, ORIS, etc. have made the process of getting data into CALMET much less of a burden.
- 3 years of MM5 data produced by Regional Planning Organizations (RPO's) for BART demonstrations have made prognostic meteorological routinely available across the lower 48 states.
- These advances have made application of CALMET much more user-friendly and has expanded the application base of the modeling system tremendously…
  - but there was a cost….

Draft IWAQM Phase 2 Revisions Acknowledged Current State of Practice

"As a result of this process, the end user (e.g. dispersion modeler) typically has little knowledge of choices made in NWP model physics options or the suitability of either the NWP or CALMET datasets used in LRT model applications. This has also created the unenviable position for reviewing authorities of having to make judgments of the suitability of NWP datasets for specific LRT applications, with little or no experience in the application of mesoscale meteorological models and an incomplete understanding of the practical limitations of diagnostic meteorological models such as CALMET in relation to their usage for air dispersion modeling."

Comments from AWMA AB-3 Committee on Meteorological Data*

Concerns

- Inconsistent acceptability
  - No obs vs Obs
  - MM5 (and which MM5), RUC, ETA
  - 36 km vs 12 km vs 4 km
- Availability
- Adequacy
- Proposed increase to 5 yrs

Recommendations

- EPA oversight for consistency and adequacy
- EPA should collect and distribute at cost

*8th Conference on Air Quality Modeling (2005)

From AB-3 2005 Comments: List of High Priority Items

- Official version free from known errors
  - with associated Users Guides
- Visibility
- ***Mesoscale met data sets***
- ***Methodology to evaluate CALMET wind fields***
- Complex wind fields
- AERMOD-like dispersion

From American Petroleum Institute: 9th Conf on Air Quality Modeling (2008)

- The widespread use of meteorological model output in air quality modeling requires:
  - ***The accuracy of MM5/CALMET model output must be tested for each dispersion model application***
  - ***EPA needs to coordinate a stakeholder group to develop guidelines for the use of meteorological models in air quality analyses***
- Meteorological model accuracy is more important than the number of years of model results used in an air quality analysis

The Current State of Practice - IWAQM Phase 2 Revisited

- Ease of use and data availability can breed complacency
  - No statistical evaluation of either prognostic or diagnostic meteorological fields as required under Appendix W, Section 8.3(d)
  - No or minimal visualization of diagnostic meteorological fields deemed critical under IWAQM Phase 2 guidance.
- EPA initially responded in May 2009
  - “The required expertise and collective body of knowledge in mesoscale meteorological models has never fully emerged from within the dispersion modeling community to support the necessary expert judgment on selection of CALMET model control options.”
  - “The lack of a sufficient body of knowledge with respect to mesoscale meteorological models, model evaluation procedures, and related issues has resulted in a process whereby the dispersion modeling community typically obtains the most readily available numerical weather prediction (NWP) dataset for applications of CALMET/CALPUFF without regard to its suitability, creates a three year CALMET dataset, and performs no additional assessment of the resulting CALMET meteorological fields. “

…And Then the Lockdown is Enforced

"*The situation described above and public comments have compelled the EPA to reassess the existing guidance and standard practices for the application of CALMET. Whereas in the past it was deemed to be both 'premature and counter-productive' to recommend specific CALMET model control options, the EPA now believes it is both timely and necessary to specify such items to promote scientific integrity and restore balance to the public decision making process.*"

- Interim recommendations from May 2009 were intended to configure CALMET as a pass through, to preserve as much of the integrity of the prognostic meteorological fields
- EPA issues Model Clearinghouse memorandum in August 2009 identifying 'preferred' CALMET model control options. Final model control options based upon EPA/FLM statistical performance evaluations (discussed tomorrow).

The Vision for the Future

- Direct coupling of prognostic meteorological models to LRT models
- Methods for evaluating prognostic and CALMET meteorological fields
- Enhanced methods for meteorological field visualization

Mesoscale Model Interface Program (MMIF)

- The **M**esoscale **M**odel **I**nter**f**ace (MMIF) *beta* program that converts MM5 or WRF meteorological output to formats appropriate for CALPUFF, SCICHEM, and AERMOD
  - Prototype by USEPA, continued development by ENVIRON
  - MMIF Version 2.1 User's Guide dated January 31, 2012
- MMIF Version 2.1 beta features:
  - Linux/Unix or Windows environment
  - Options to re-diagnose or pass-through PBL depth
  - Can process subset of MM5/WRF domain
  - An option to perform layer aggregation
  - Retains original MM5/WRF map projection and horizontal grid resolution
  - Support for Polar Stereographic and Mercator projections

CALPUFF

- Two options for defining PG stability
- Generates a CALMET.DAT format file that can be directly input to CALPUFF
- Also generates CALMET.AUX format file containing the 3D cloud liquid water mixing ratio for CALPUFF version 6.X
- Option to extract MM5/WRF data based on Latitude/Longitude window rather than just (i,j) offset
- Option to use WRF/MM5 LAI, L and z0 estimates rather than lookup table approach (i.e., pass through)
- Designed to retain projection and grid resolution of original prognostic meteorological data

AERMOD

- For AERMOD, three options to output data for user selected location (MM5/WRF grid cell):
- Output surface and upper-air meteorological data to run through AERMET
- Output meteorological data in AERCOARE format (then run AERCOARE)
- Create AERMET-like output surface and profile files

SCICHEM

- MMIF generates meteorological inputs to SCICHEM in the MEDOC format
- MEDOC format can optionally be ASCII or binary
- MMIF also generates a receptor sample location file which includes the X,Y, and Z of all points in the output domain or sub-domain

Testing and Evaluation of MMIF

- Forms of evaluation
  - Qualitative diagnostic evaluations comparing MMIF output to CALMET “NOOBS” - ENVIRON testing
  - Quantitative performance evaluations for both meteorological and air quality models – will be discussed tomorrow during Ralph Morris presentation
  - Qualitative and quantitative consequence analysis for use in AQRV assessments – USFWS (today) and ENVIRON (tomorrow)

Testing and Evaluation

- Comparison of MMIF and CALMET (no obs option) 10 m wind vectors
- Both approaches are superimposed but difficult to see both color vectors as they are nearly identical

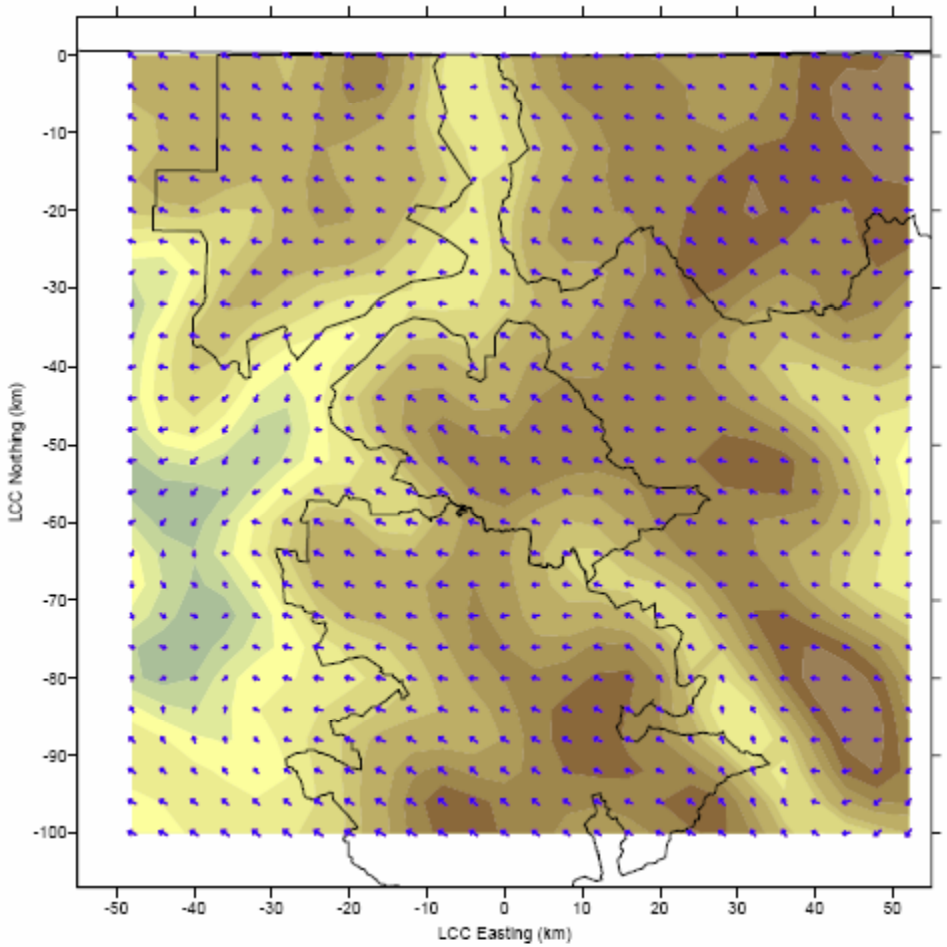


Figure 2. MMIF 10 m winds (blue) and CALMET winds (red) for 12:00 LST, January 1, 2005.

Figure generated by ENVIRON

Testing and Evaluation

- Comparison of MMIF and CALMET 10 m temperature
- Both approaches show similar spatial patterns and magnitudes

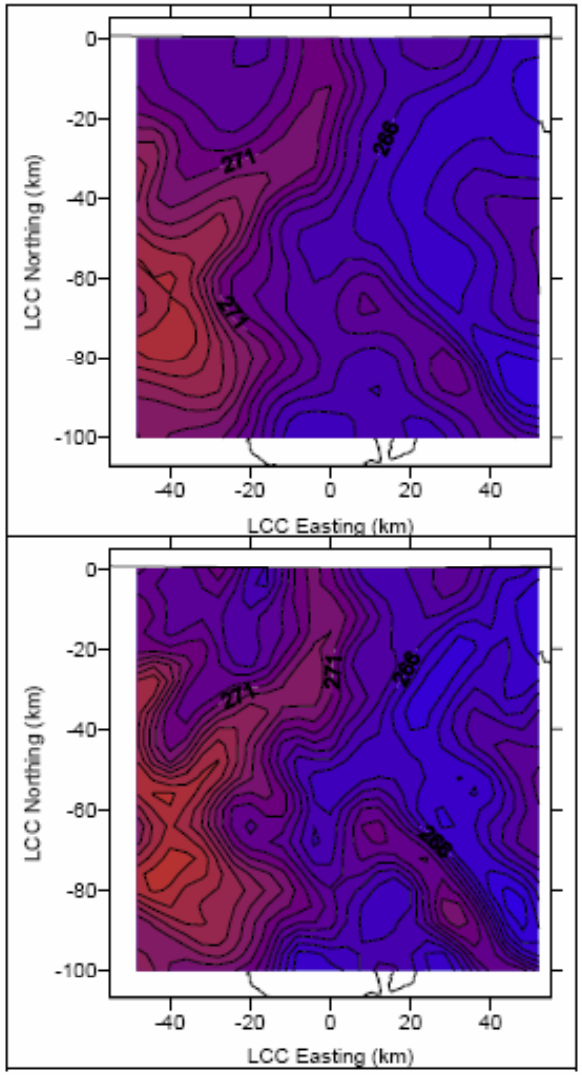


Figure 4. 10 m temperature from CALMET (top) and MMIF (bottom) at 12:00 LST, January 1, 2005.

Figure generated by ENVIRON

Testing and Evaluation

- PBL height (left) and PG class (right) show less agreement between CALMET and MMIF

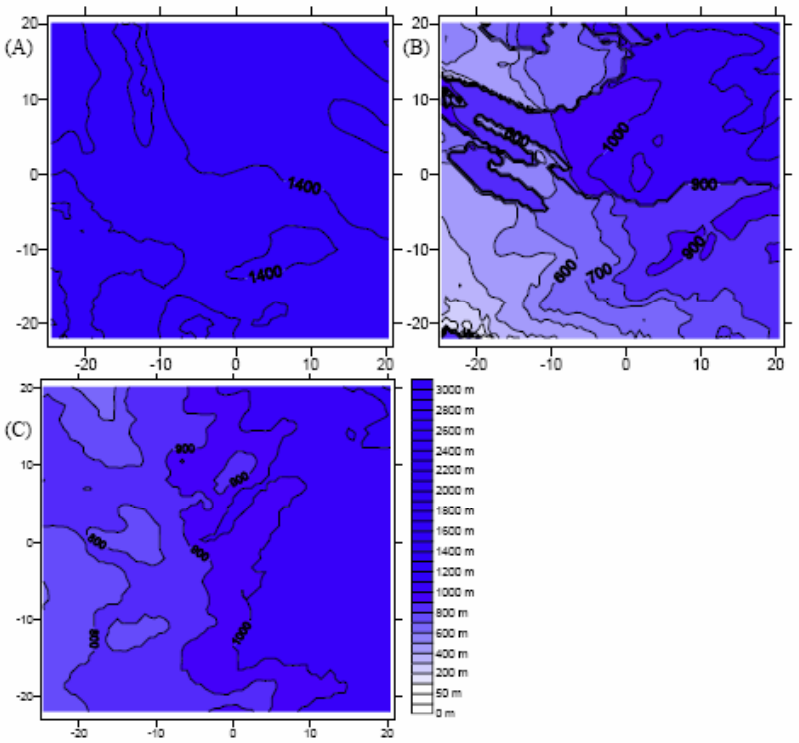


Figure 12. PBL Height from (A) CALMET, (B) MMIF via the "pass-through" option, and (C) MMIF via the "re-diagnosis" option, at 18:00 LST, 1994-04-24.

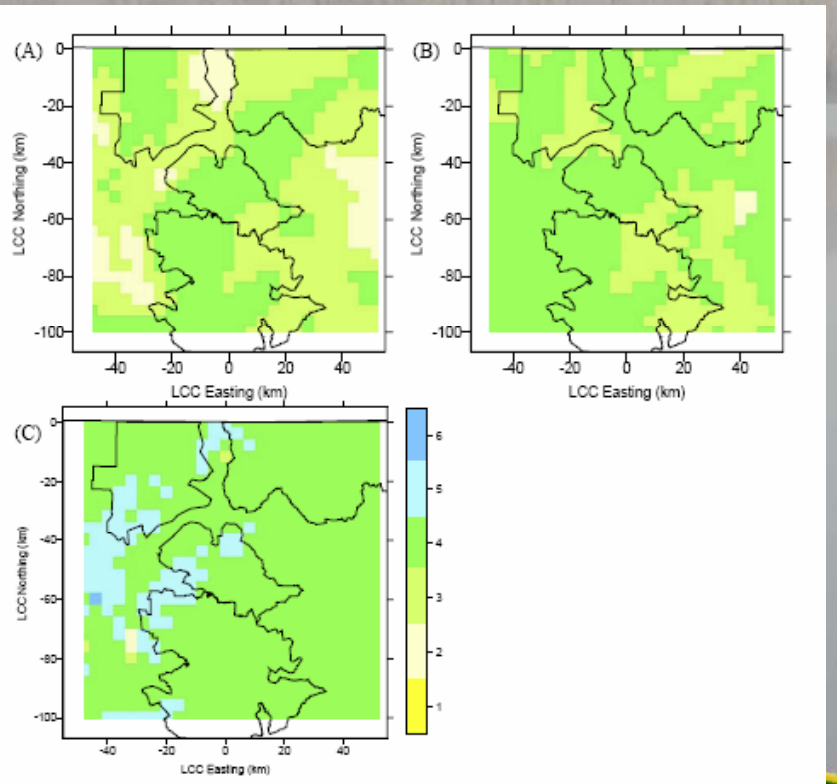


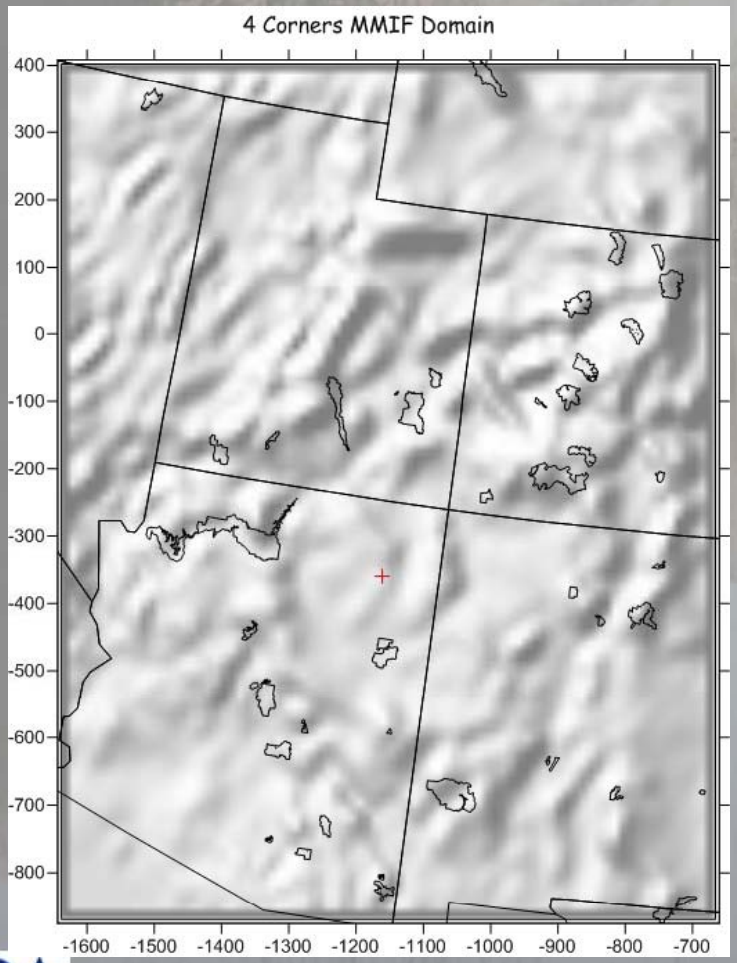
Figure 5. PG Stability Class for (A) CALMET, (B) MMIF with PG Method 1, (C) MMIF with PG Method 2, at 12:00 LST, January 1, 2005.

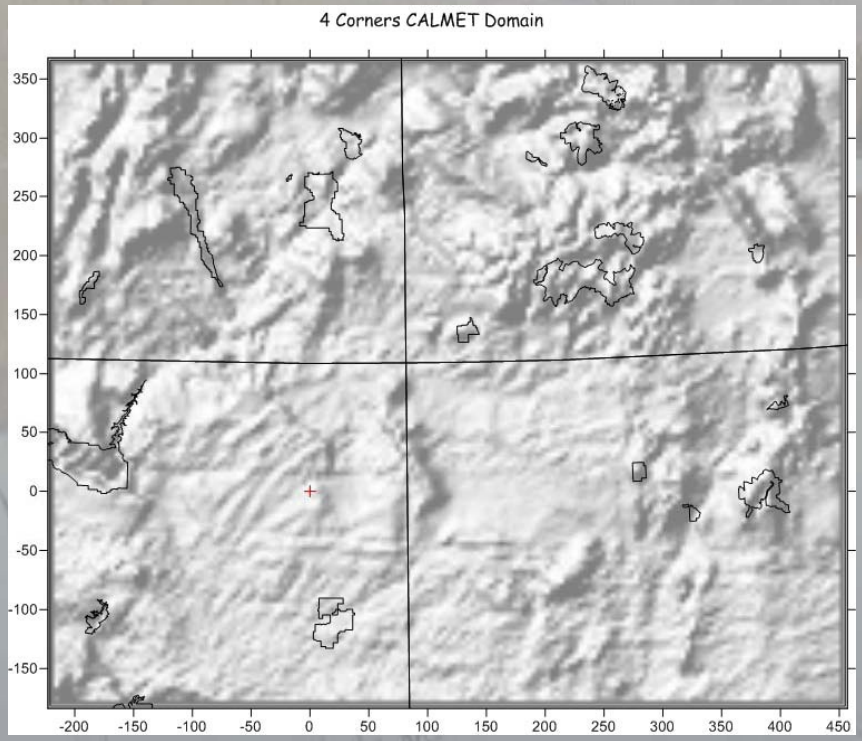
Figures generated by ENVIRON

FLM Testing of MMIF

- Conducted by US Fish and Wildlife Service for MMIF 1.0
- Consequence analysis of CALPUFF results examining differences between CALMET and MMIF. Key concern was to examine effect of prognostic fields on AQRV's (visibility, deposition).
- 3 Domains were developed to test MMIF under climatological regimes
  - Four Corners
  - North Dakota
  - VISTAS Domain 5
- Analysis of effect of wet deposition (on/off), dry deposition
- Emissions Scenarios Tested:
  - 2 stack EGU
  - Cement Plant

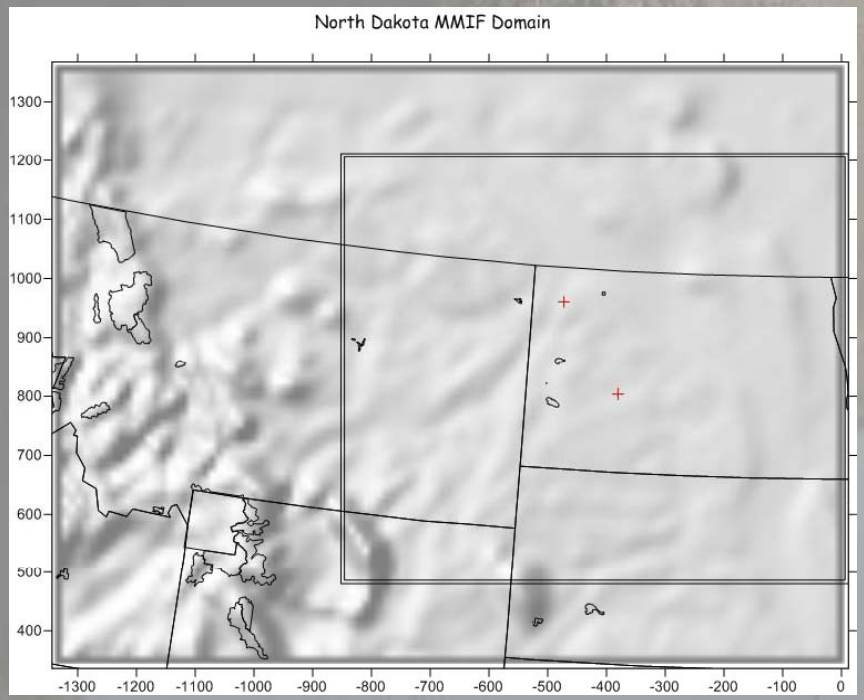
Four Corners Domain

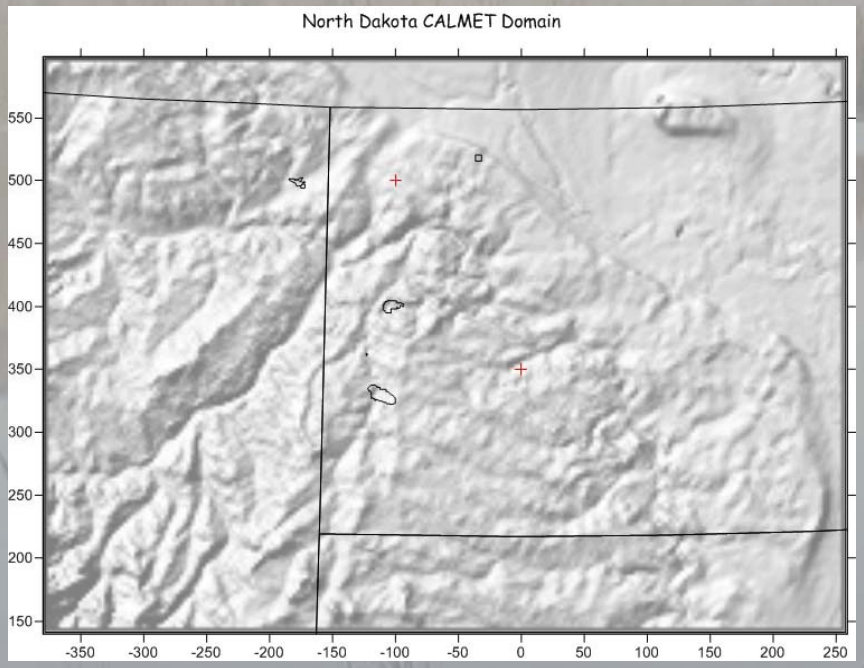




Figures generated by USFWS

North Dakota Domain





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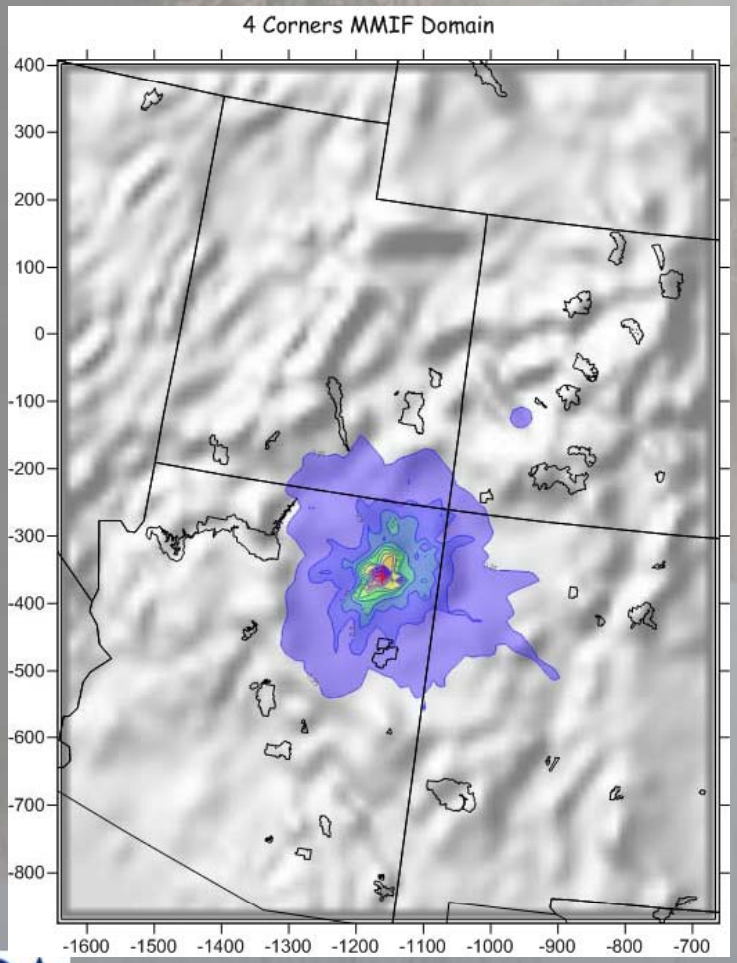
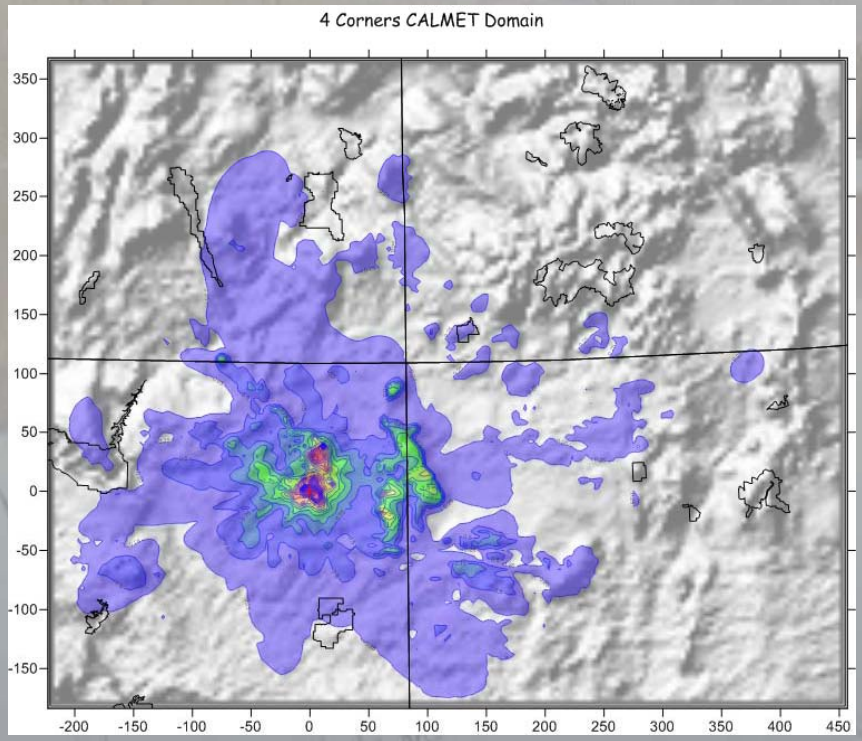
Deposition – Four Corners Domain





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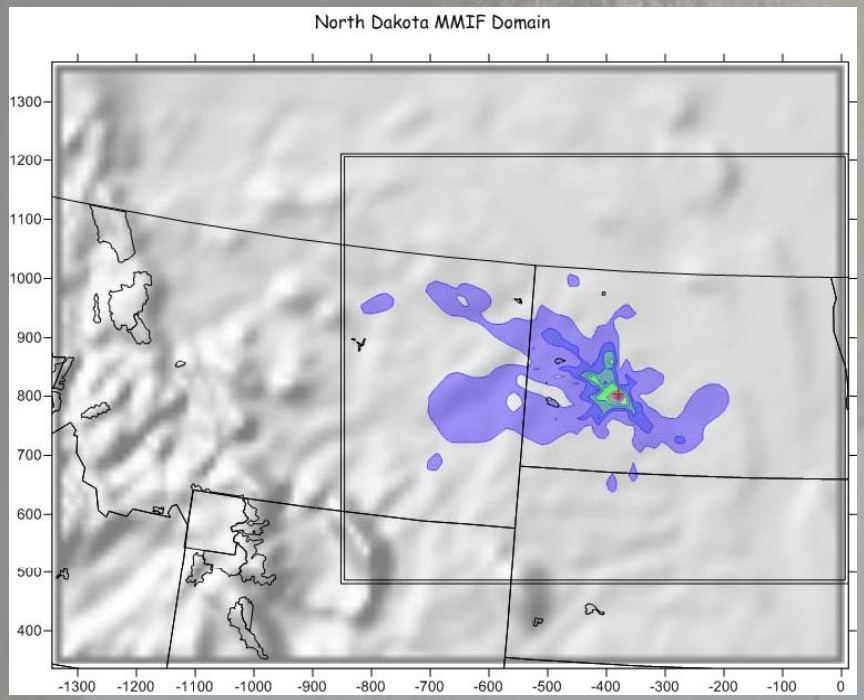
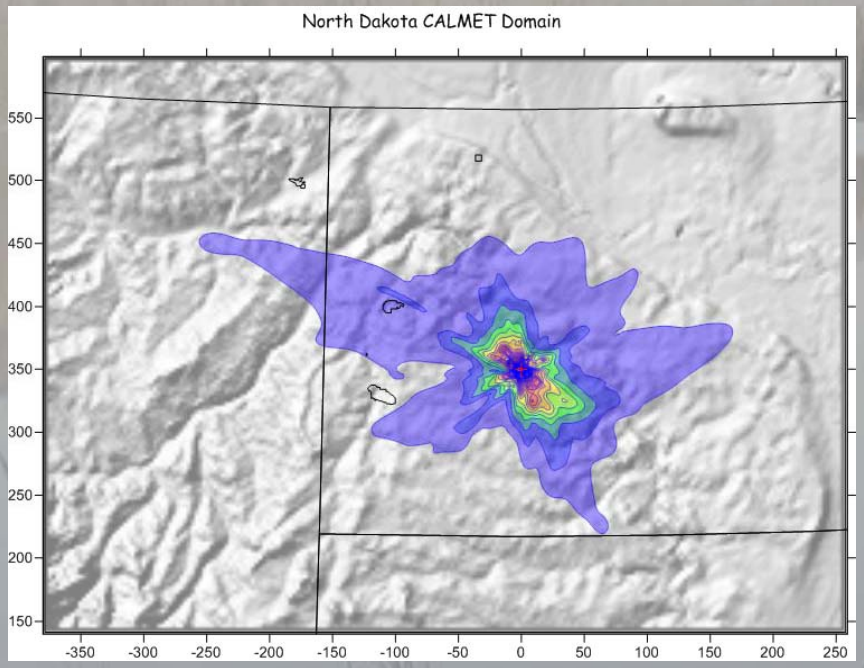
Deposition – North Dakota Domain





Figures generated by USFWS

Initial Observations from FLM Testing

- Significant differences noted in deposition levels and patterns between MMIF and CALMET results.
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  - Possible Causes:
    - Stability
    - Mixing Heights
    - Precipitation
    - Transport directionality
- Additional examination of results is necessary in order to make more definitive conclusions.
- Important to reiterate that this is not a model validation exercise rather these tests are designed to examine the effect of different methods of supplying meteorological data to the dispersion model and their subsequent effects on AQRV's.

MMIF Testing and Evaluation

- Comprehensive testing of MMIF tool done against tracer release field studies (USEPA/USFS and ENVIRON)
- CALPUFF applied with CALMET and MMIF for various tracer release experiments (ETEX, CAPTEX, and GP80)
- Plume placement generally comparable or better when using MMIF for these tracer experiments
- Final Report “Documentation of CALPUFF and Other Long Range Transport Models using Tracer Test Field Experiment Data” (ENVIRON, February 2012)
  - **http://www.epa.gov/ttn/scram/reports/LRT_Tracer_Final_Feb13_2012.pdf**

MMIF Testing and Evaluation (cont)

- The MMIF tool was used to prepare meteorological inputs for SCICHEM for the 1999 TVA plume measurement study
- Plume placement using MMIF generated meteorology consistent with using SCICHEM with meteorological observations as inputs
- Plume placement using MMIF/SCICHEM also consistent with CMAQ (MCIP) and CAMx (wrfcamx)

MMIF Support

- U.S. EPA/ENVIRON has already made several code updates to MMIF since the original posting on SCRAM in mid-February to address reported bugs
- The updated beta code is available on SCRAM
- US EPA continues to compile bugs and issues with the program and documentation
- Periodic releases are planned for MMIF; the next update being Fall 2012

Related Software

- **MMIFSTAT** – Uses MMIF output in CALMET file format as input with user supplied observations to generate performance statistics and prediction-observation pairs for plotting (Windows and Linux version on SCRAM). Prototype developed by EPA Region 7, funding provided by US Forest Service, US Fish and Wildlife Service, National Park Service, and EPA Region 10 for Alpine Geophysics to develop the current MMIFSTAT beta.

- **CALMET2NCF** – Program converts CALMET binary output files to netCDF/IOAPI format that can be visualized by the public available programs like PAVE/VERDI, IDV, NCL, and GrADS. Developed by USFS as part of the BlueSky framework, adapted by EPA OAQPS for standalone use to provide seamless bridge to numerous visualization platforms

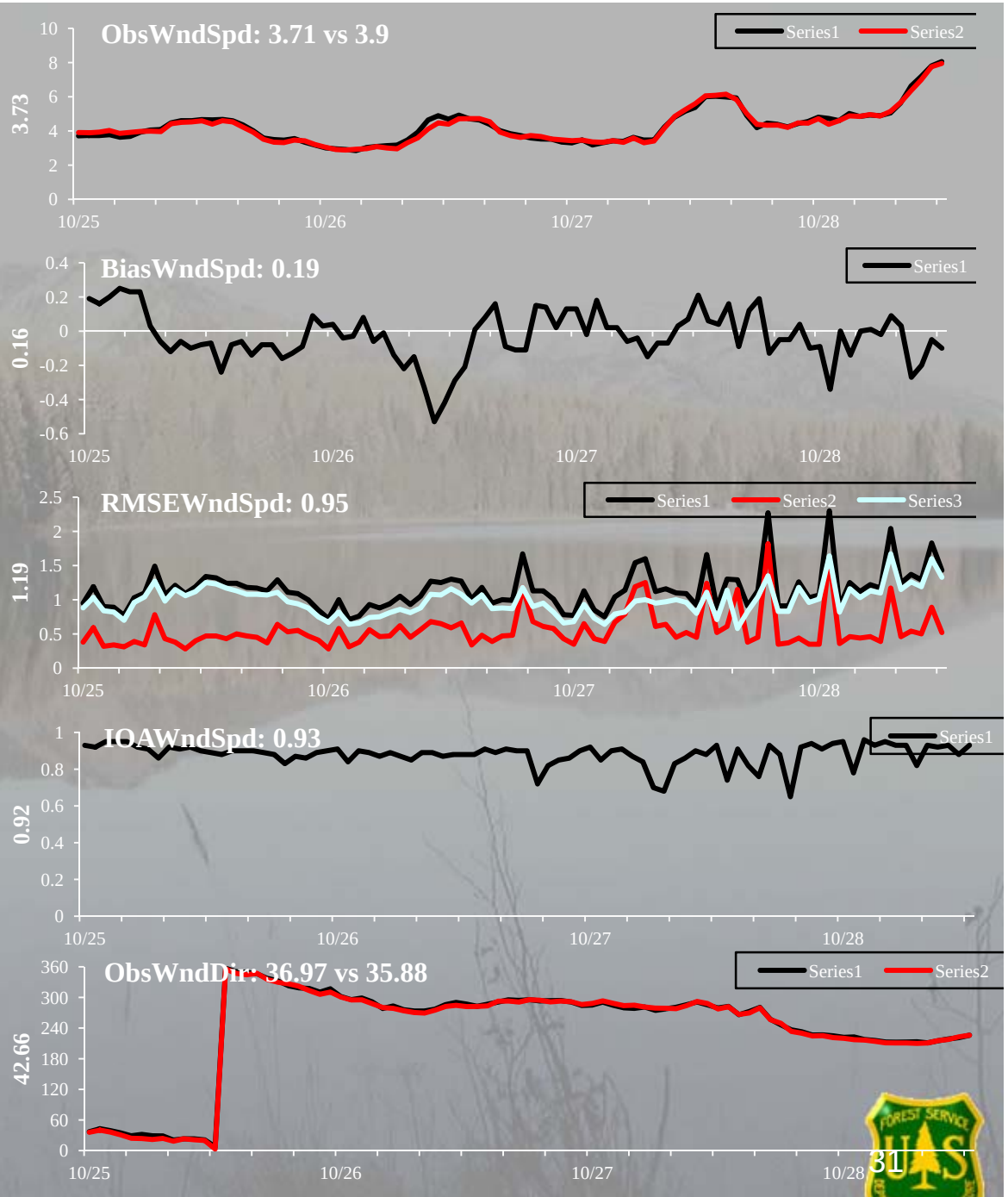
http://www.epa.gov/ttn/scram/dispersion_related.htm

MMIFSTAT

Statistical performance evaluation package for CALMET formatted meteorological files. Provides basic statistical measures for winds, temperature, and humidity. Designed after ENVIRON's METSTAT program by Alpine Geophysics.

Features include:

1. Provides basic statistical analysis of primary meteorological variables
2. Runs on numerous operating systems including Linux and Windows.
3. Provides Excel macro to provide visualization of hourly time series and daily summaries of statistics
4. It is freely available to the public.

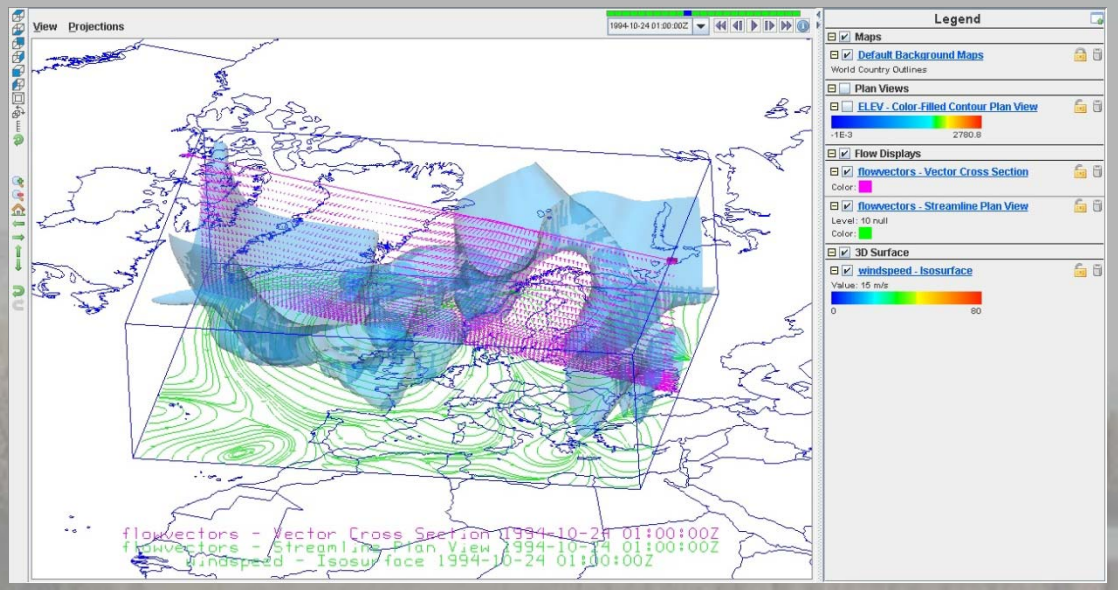


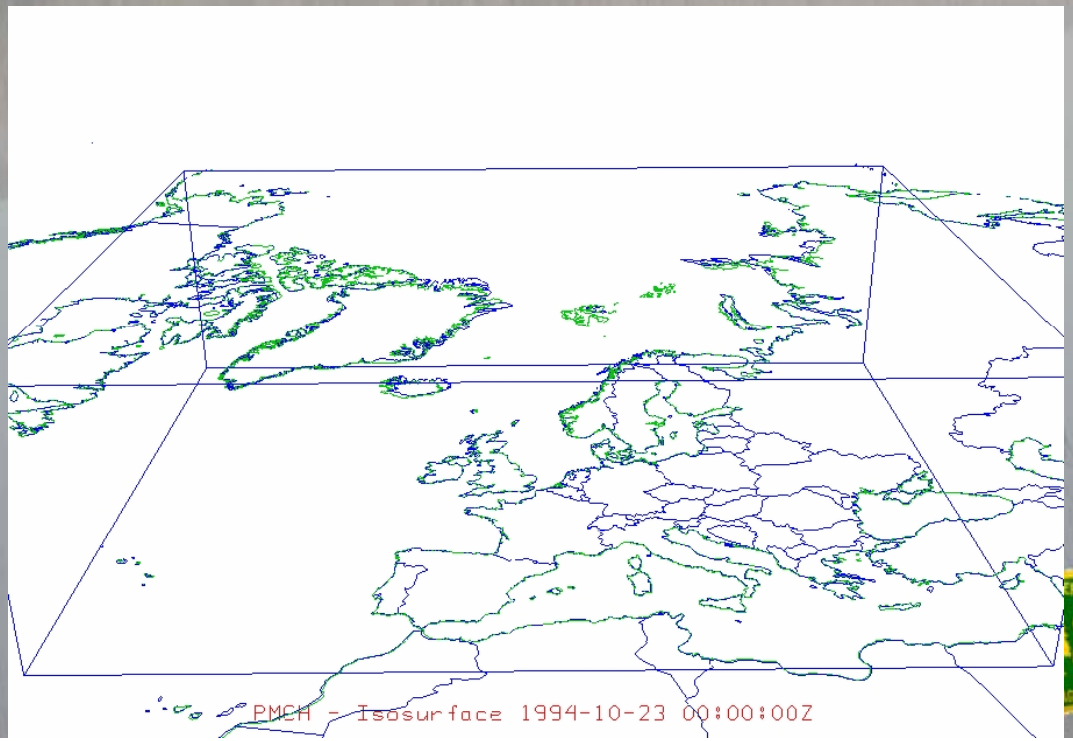
Integrated Data Viewer

Integrated Data Viewer (IDV) from Unidata/UCAR is a Java based software framework for analyzing and visualizing geoscience data. The IDV release includes a software library and a reference application made from that software. It uses the VisAD library and other Java-based utility packages.

Features include:

1. File handling for netCDF, HDF, GRIB binary, and ASCII
2. Runs on numerous operating systems including Linux and Windows.
3. It is freely available to the public.



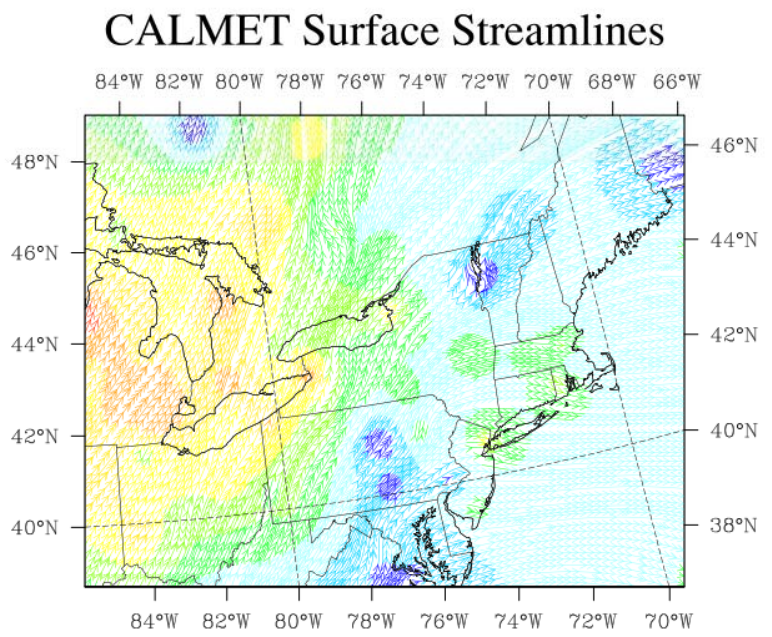


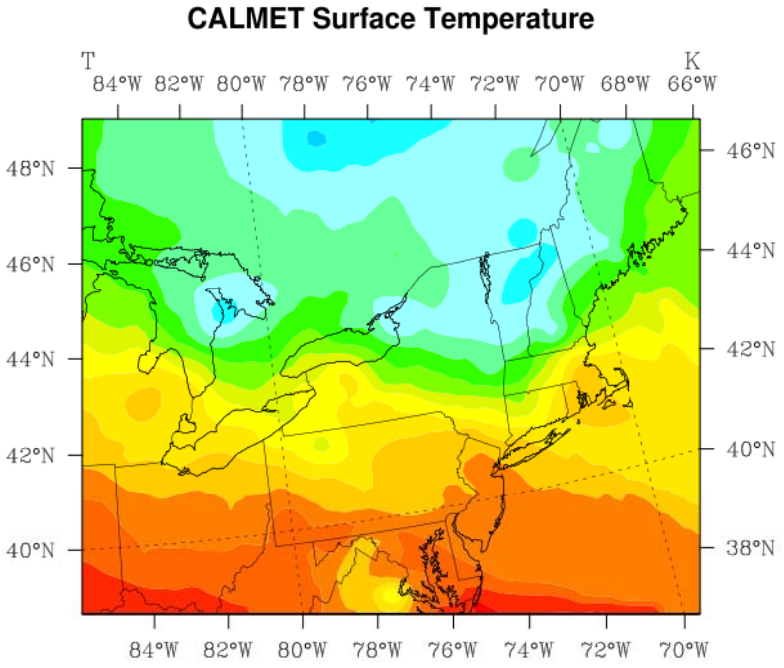
NCAR Command Language

The NCAR Command Language (NCL) is a free interpreted language. Designed by the National Center for Atmospheric Research (NCAR) for scientific visualization and data analysis.

Features include:

1. File handling for netCDF, HDF, GRIB binary, and ASCII
2. Runs on numerous operating systems including Linux and Cygwin/X running under Windows.
3. It is freely available to the public in both binary and source code formats



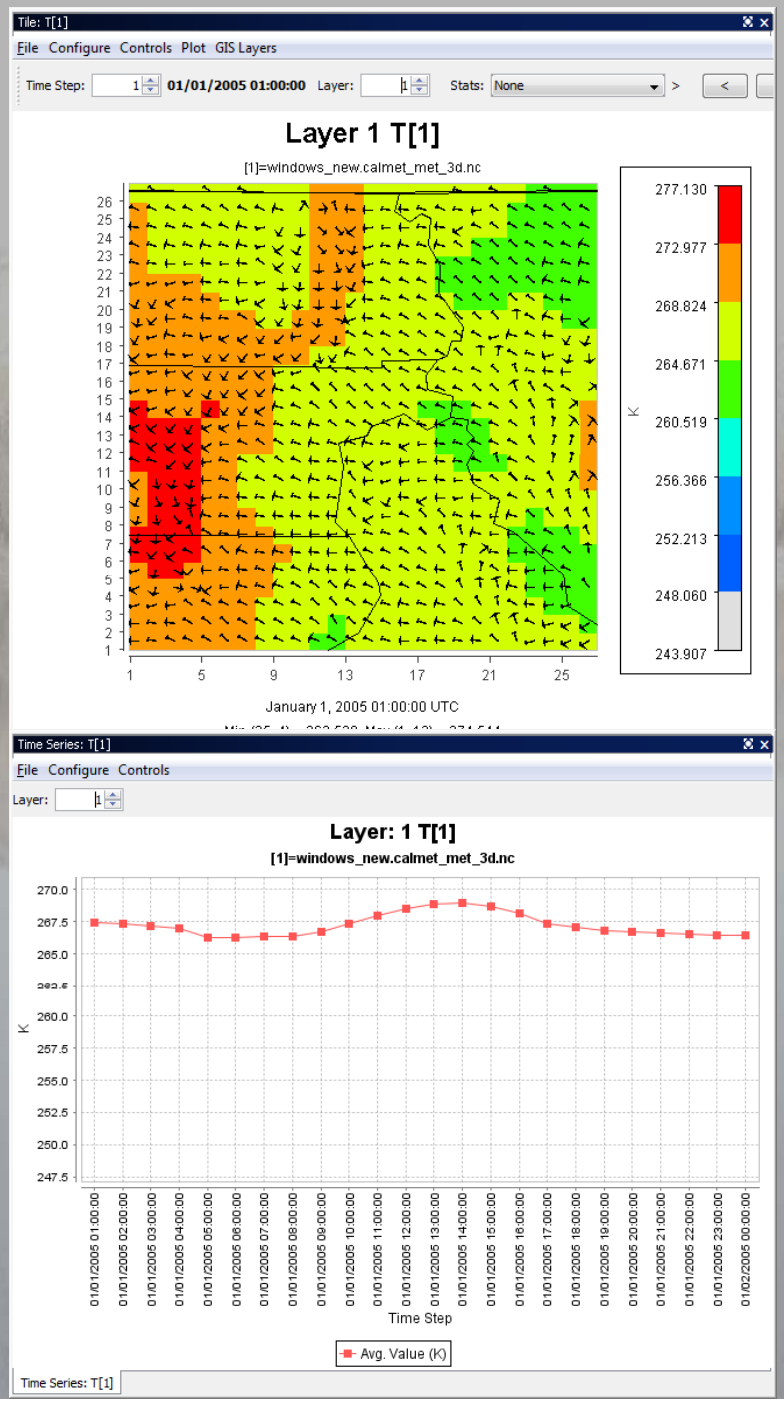


VERDI

Visualization Environment for Rich Data Interpretation (VERDI) is a Java program for visualizing meteorology, emissions, and air quality modeling data.

Features include:

1. File handling for netCDF (M3 IOAPI), UAM formatted, and ASCII data
2. Runs on numerous operating systems including Linux and Windows.
3. It is freely available to the public in both binary and source code formats



Summary of Testing

- It is important to note that testing to date does not indicate a superior performance advantage of MMIF over CALMET. MMIF is not a “silver bullet.”
  - Statistical performance evaluations show better performance for some tracer evaluations, worse for others
- For regulatory agencies, it can provide confidence and consistency in meteorological data sets produced for LRT modeling assessments
- For the community, it can provide lower costs and reduced project timelines for LRT model assessments.
  - Significant time and financial resources are associated with the development of meteorological inputs to LRT models

Where Does the Community Go From Here?

- EPA's Second Essential Element:
  - *"Promote and facilitate the use of gridded meteorological data including "state-of-practice" National Weather Service (NWS) meteorological analyses to improve modeling science and performance for near-field modeling applications (permits, toxics, direct PM)."*

- Draft IWAQM Phase 2 revisions in 2009 discussed one potential
  - Released to support discussion of May 2009 EPA Model Clearinghouse memorandum in response to EPA Region 8 request on CALMET grid resolution issue.
  - Released prematurely as many elements (MMIF, MMIFStat, and visualization tools) were still under development…
  - However, revisions reflected the vision to address EPA's second element as well as many of the long standing concerns identified by both AWMA AB-3 and API at the 8th and 9th Conferences on Air Quality Modeling regarding use of prognostic data and CALMET.

Draft Revisions to IWAQM Phase 2 Recommendations

- The revised IWAQM recommendations strictly imply that the candidate NWP data used should appropriately characterize the key meteorological features that govern source-receptor relations for the specific application.
- This places a higher emphasis on ensuring that the candidate NWP dataset is at the appropriate horizontal grid resolution ***and*** that the dataset captures the key meteorological features for the specific application.
  - Therefore, the recommendation for establishing the suitability of NWP dataset under Section 8.3(d) of the *GAQM* is a critical component for planning a successful LRT model application. In light of these concerns, the appropriateness and adequacy of the CALMET/CALPUFF grid resolution, as well as any prognostic model data used as input to CALMET, should be adequately justified based on the specific needs of the application, and measures should be taken to objectively assess the resulting meteorological fields,

Draft IWAQM Revisions – cont'd

- In accordance with Section 8.3(d) of the *GAQM*, EPA must reemphasize that acceptance of a prognostic data set is contingent upon concurrence from the appropriate reviewing authority. Therefore, at a minimum, any protocol should include an evaluation of the performance of the candidate NWP dataset prior to acceptance by the reviewing authority.

Next Steps

- Continue to get feedback and input from community on beta release
- Begin process of developing guidance on use of MMIF, as appropriate
- Meteorological model evaluation procedures
  - Current paradigm focuses heavily upon surface analysis
  - Need for upper air analysis
  - Need for precipitation analysis
- Updates to MMIFSTAT
  - SCICHEM/MEDOC format
  - CALMET 6.x support
  - Polar Stereographic, Mercator projections
- Federal Land Managers (USFWS/USFS) in process of developing national coverage of MMIF data for AQRV assessments
  - Will provide MMIF coverages for US based upon WRF development (USEPA, WRAP WestJumps project, etc.). Similar to successful approach used by VISTAS used for development of CALMET domains for BART evaluations.
  - Performance evaluations will be conducted on each domain to provide data and performance statistics for those that wish to use these data sets
  - Independent prognostic data will require meteorological performance evaluation in accordance with final performance evaluation guidance

Acknowledgements

- Kirk Baker, USEPA MMIF Project Work Assignment Manager
- Bart Brashers and Chris Emery – ENVIRON software development team
- Dennis McNally – Alpine Geophysics for MMIFStat development
- US Fish and Wildlife Service – Initial FLM testing of MMIF
- USEPA OAQPS – providing ongoing MMIF funding for development and maintenance
- National Park Service, US Fish and Wildlife Service, US Forest Service, and EPA Region 10 for funding for MMIFSTAT development
- Forest Service AirFire Team/UNC Environmental Programs/EPA for CALMET2NCF development