

GRAPHICAL AND ANALYTICAL SOFTWARE VISUALIZATION TOOLS FOR EVALUATING METEOROLOGICAL AND AIR QUALITY MODEL PERFORMANCE

Irene Lee *
Exponent Inc., Natick, Massachusetts

1. INTRODUCTION

A critical part of meteorological and air quality modeling is evaluation of the output modeled data in order to accurately assess model performance. Visualization can be an indispensable tool in this, not only in initial model setup, but also in helping to identify and diagnose any potential problems in a modeling run.

Toward this goal, we have developed CALApps, a freely distributed software package that allows users to quickly and seamlessly visualize and assess model input and output data. The data formats read by the software are all in non-proprietary human-readable ASCII format which allows any type of data to be displayed with a simple format conversion. This includes data from numerical weather prediction models such as WRF, MM5, NAM, ECMWF, RAMS, Rapid Refresh Model (RAP), ETA, data from the CALPUFF dispersion modeling system including CALMET and CALPUFF, as well as observed meteorological data such as ISHWO surface observations and FSL upper air soundings.

2. OVERVIEW

The CALApps software package currently includes two tools: CALApps Viewer to plot terrain and land-use base maps with animated two-dimensional meteorological field and concentration contour overlays, and CALApps Timeseries to display time series interactively.

* *Corresponding author address:* Irene Lee, Exponent, Inc., 6 Strathmore Rd., Natick, MA 01760; e-mail: ilee@exponent.com.

2.1 CALApps Viewer

CALApps Viewer (shown in Figure 1) allows users to overlay two-dimensional meteorological fields including wind vectors, temperature, precipitation, mixing height, and stability class, as well as concentration contours, over a base map of terrain and/or land-use.

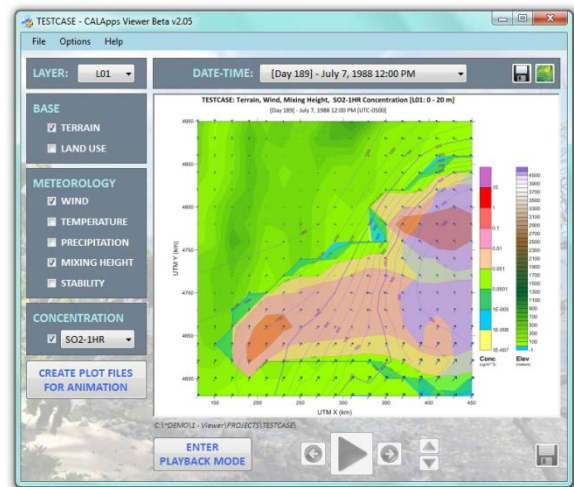


Figure 1. CALApps Viewer

Visible layers may be turned on and off via checkboxes, individual dates and times can be selected from the pull-down list of all available dates and times in the working directory, and, for three-dimensional fields, specific vertical layers can be selected.

Selected maps can be animated and played within the software with built-in options to play and pause the animation, increase and decrease the playback speed, and step forward and backward frame-by-frame through the animation.

Individual frames can be saved to picture files including JPG, BMP, and GIF, and the animations can be saved to animated GIF files.

The animated GIF files can be played

outside the software in any web browser or inserted into PowerPoint. When inserted into PowerPoint as pictures, multiple animated GIF files can be played simultaneously in step with each other. This is particularly useful for sensitivity analyses to determine the impact of different model options or input data.

Numerous custom options also exist in CALApps Viewer, including the option to import a custom base map such as an aerial photo or plant blueprints, or add source and meteorological station locations. Additional options allow the user to control the transparency of each layer, select custom topography and concentration contour levels, and scale the length of the wind vectors.

2.2 CALApps TimeSeries

CALApps TimeSeries (shown in Figure 2) allows users to plot up to six time series simultaneously.

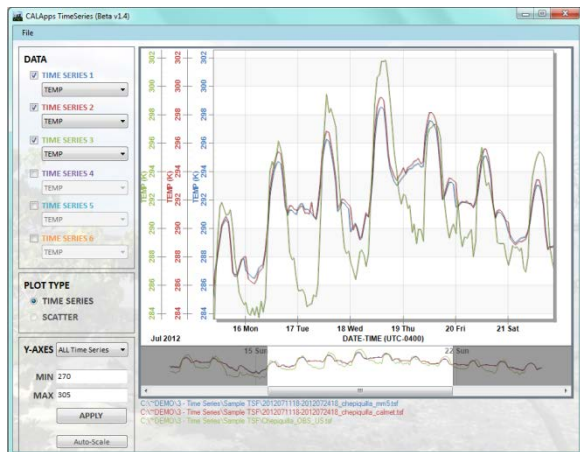


Figure 2. CALApps TimeSeries

The user can interactively zoom into and scroll through the selected time series. By hovering with the mouse, individual data points can be manually selected to show the exact time and value of each plotted point. Time series can also be quickly checked on and off.

When two time series are selected, the user also has the option to view the data as a scatter plot.

The Y-axes for each time series are automatically scaled to optimize display.

Alternatively, the Y-axis scales can be set to be identical in order to easily compare various time series of the same variable. The Y-axes may also be individually and manually set.

The displayed time series can be saved as a picture file.

3. EXAMPLES

In this section we discuss three real-life applications of the CALApps software. CALApps is particularly useful in analyzing and evaluating CALPUFF applications. CALPUFF is a U.S. EPA Approved *Guideline* model. Typical uses of CALPUFF include modeling long-range transport greater than 50 km, National Ambient Air Quality (NAAQS) analyses, Prevention of Significant Deterioration (PSD) analyses, and Air Quality Related Values (AQRVs) in Class I areas including visibility and pollutant deposition.

CALPUFF has a strong meteorological component with links to WRF, MM5, NAM, ECMWF, RAMS, RAP, and CALMET.

3.1 Complex Terrain

The first example is a CALPUFF application in complex terrain with a non-buoyant release in a deep and sinuous valley, upwind from an area of interest. The purpose of the modeling was to assess the impact of the source on that area of interest.

CALApps Viewer can quickly plot the terrain, locations of the source and surface meteorological stations, and also highlight the area of interest.

The source (shown in red in Figure 3) is located at the eastern side of the East-West portion of the valley. There are four meteorological stations within the valley, (shown in blue in Figure 3) upon which the meteorological modeling is based. The area of interest is located at the mouth of the valley downwind and northwest of the source.

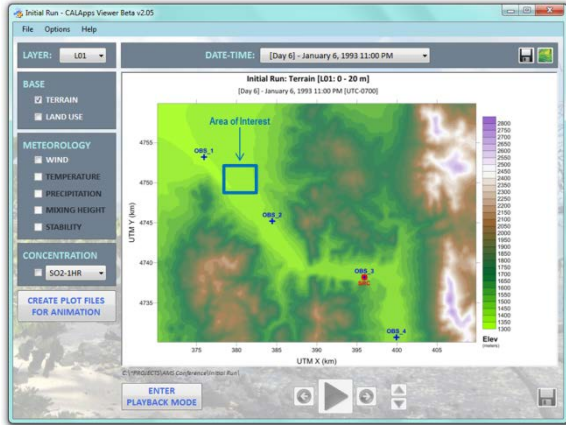


Figure 3. Complex Terrain Example

An initial run (shown in Figure 4) shows the plume of pollutant leaving the source before erroneously jumping out of the valley, instead of following it, and consequently having little to no impact on the area of interest.

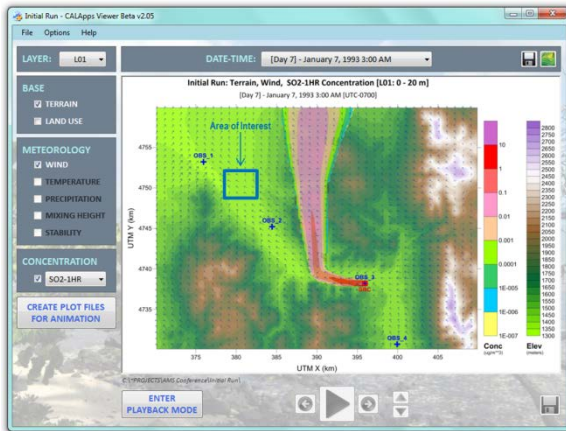


Figure 4. Complex Terrain Example – Initial Run

By optimizing the CALMET model options, the winds were corrected and the pollutant plume then correctly meandered inside the valley passing directly over the area of interest (shown in Figure 5).

The ability to quickly visualize the plume, and the relative locations of the source, surface meteorological stations, and area of interest overlaid on the complex terrain features, allowed the modeler to spot the inconsistency between the plume trajectory and complex terrain features, to evaluate alternative options and optimize the simulation.

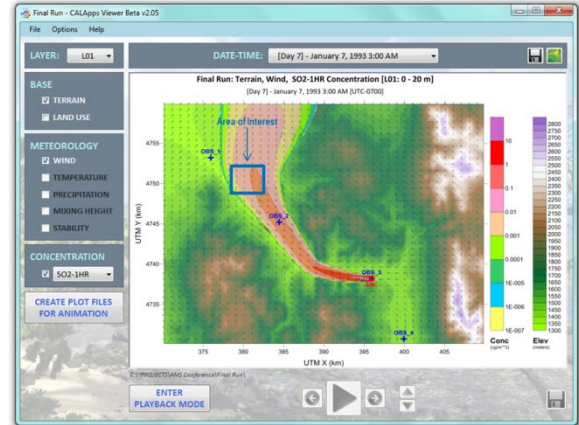


Figure 5. Complex Terrain Example – Final Run

3.2 European Tracer Experiment (ETEX)

CALApps Viewer can create animated GIF files of model simulations which can be inserted into PowerPoint as pictures. This allows the model runs to be played in-step with each other, quickly revealing the impact that various model settings and/or input data have on the resulting fields.

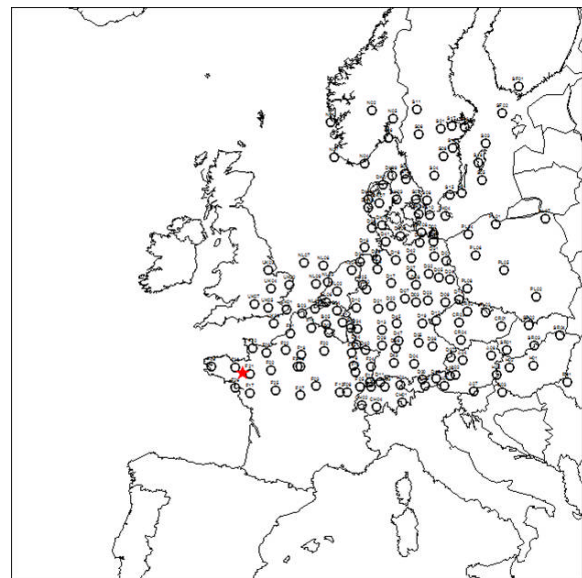


Figure 6. European Tracer Experiment

The European Tracer Experiment (ETEX) was designed for emergency response model evaluation. A twelve-hour release of PM₁₀ tracer was released on October 23, 1994 beginning at 16:00 UTC from northwestern France (shown in red in Figure 6). Three-hour

average samples were recorded at various times over 168 samplers (shown as black circles in Figure 6) across seventeen countries. The majority of the samplers were located over 300 km away, with tracer measured up to over 2,000 km from the release site.

The ETEX experiment was used by EPA/Environ in a set of long-range transport model evaluations that included an analysis of CALPUFF. Their conclusion, though incorrect, was that CALPUFF under-performed.

However, EPA/Environ’s analysis had several model setup errors and used coarse 36 km resolution MMIF data as meteorological input. The result, shown in Figure 7, was poor characterization of the winds at the tracer release site which led to the entire tracer mass being caught into the wind circulation to the northwest, largely missing the field of samplers.

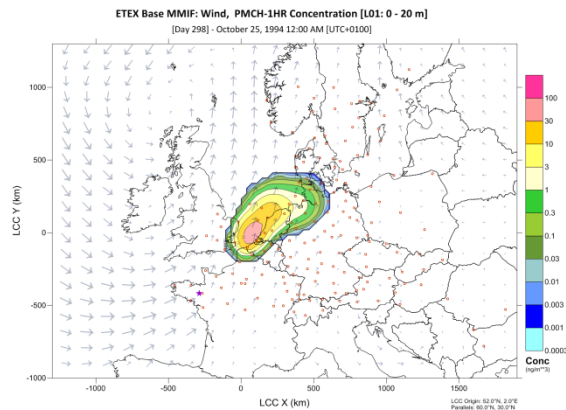


Figure 7. ETEX – EPA/Environ Run

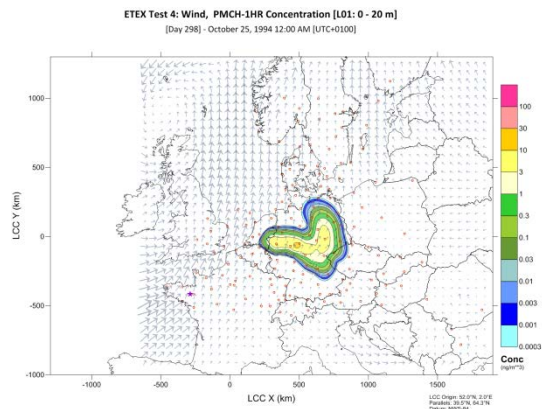


Figure 8. ETEX – Exponent Run

However, with a correction to the model setup errors and using refined 12 km resolution

CALMET input data instead, the winds at the tracer release site resulted in the tracer mass being caught not only into the circulation to the northwest but also by the divergent wind flow to the east (shown in Figure 8). This stretched the tracer mass over much of the sampling field and as a result, CALPUFF actually performed among the best of the models included in the analysis.

Full animations of both the EPA/Environ and Exponent CALPUFF model ETEX simulations, as well as an animation showing six different model runs playing in-step with each other, were created with CALApps Viewer and can be viewed in the PowerPoint presentation that accompanies this paper.

3.3 The Northwest Passage: Sea Ice

CALApps TimeSeries can plot multiple time series simultaneously with the option to interactively zoom, pan, and scroll through the various time series.



Figure 9. The Northwest Passage

Polar MM5 was run on an area in Arctic Canada including the Northwest Passage at two different resolutions, on a coarse 30 km and a fine 10 km grid.

In the course of validating these runs, CALApps TimeSeries was used extensively to plot modeled and observed variables. In particular the coarse and fine resolution MM5 surface temperatures were plotted against observations at a station on the shore of the Northwest Passage.

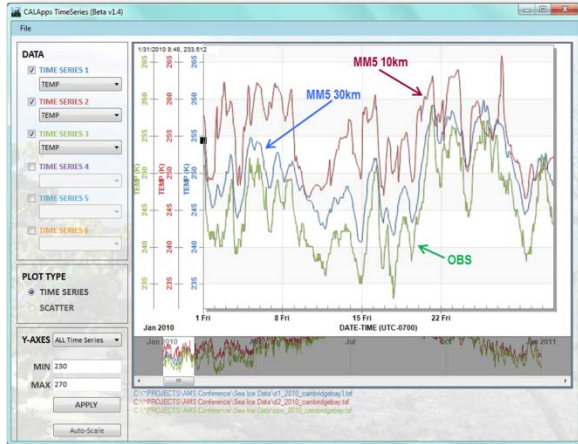


Figure 10. The Northwest Passage – Temperature Time Series

Zooming in to the month of January (shown in Figure 10) revealed a problem in the simulations: the coarse resolution MM5 run was performing better than the fine resolution MM5 simulation in terms of surface air temperature, and both runs indicated surface air temperatures much warmer than observed over the Northwest Passage. It was determined that due to erroneous RTG SST data, the Northwest Passage was in fact ice-free in the dead of the arctic winter and the MM5 air temperatures were influenced by gridded sea surface temperatures above the freezing point of sea water.

The problem was partially compensated by FDDA in the coarse MM5 run, explaining the discrepancy between the coarse and fine resolution results. This otherwise hidden flaw of the RTG SST dataset was revealed through the use of CALApps Timeseries. The issue was then solved by switching to another SST dataset, with more realistic winter temperatures.

4. DATA FORMAT

The data formats read by the CALApps software package are all in a non-proprietary human-readable ASCII format. An example of the format read by CALApps TimeSeries is shown in Figure 11.

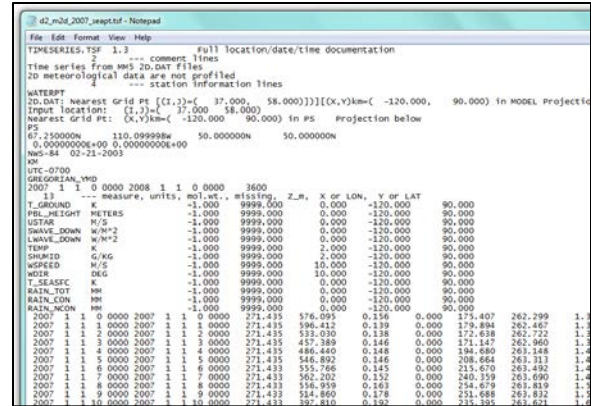


Figure 11. CALApps TimeSeries – File Format

5. FUTURE DEVELOPMENTS AND DISTRIBUTION

The entire CALApps software package will be distributed free of charge from the Exponent web site at:

http://www.exponent.com/atmospheric_sciences

Additional tools and options are currently being developed and added to the CALApps software package.

A full graphical user interface (GUI) for the CALPUFF modeling system and all related processors is in development and anticipated for release in early 2013 (Figure 12). This new GUI is compatible with both 32-bit and 64-bit Windows 7 and earlier operating systems.

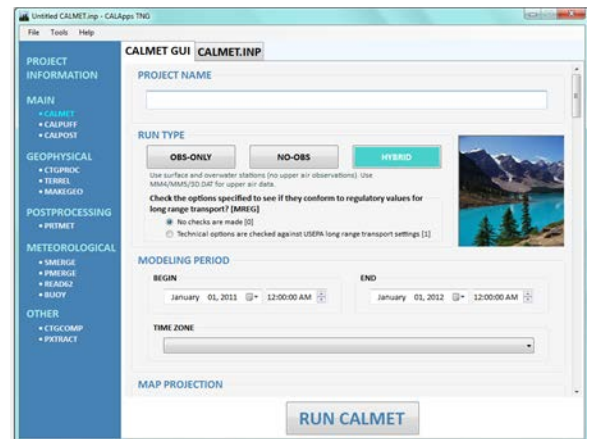


Figure 12. CALApps Software Package – CALMET