

A Regional Air Quality Assessment with CALPUFF Modelling on a Grid Computing Platform

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Project

- ▶ Evaluates the adverse effect of sulphur dioxide emissions from thermal power plants on air quality for varying emissions scenarios.
- ▶ Dispersion modelling using CALPUFF over entire country and 5 years of meteorological data necessitates large scale computation.
- ▶ Estimated to take 336 days of computation for a bank of 14 Xeon processors to complete all the calculations.
- ▶ Applying efficient and inexpensive distributed computing solution and "best-practices" of modelling techniques reduces the project execution to one month instead of one year.

Introduction

- ▶ CALPUFF is a Lagrangian puff-tracking air dispersion model for regulatory applications in the U.S.A. and many Canadian provinces.
- ▶ CALMET is a diagnostic meteorological processor included in the CALPUFF system. It creates local wind field forced by topography or land-sea temperature contrast.
- ▶ CALMET does not use the full mass, momentum, and energy conservation equations. Therefore, it generally benefits from results of a prognostic model such as MM5.
- ▶ CALPUFF is intolerantly slow because it has to track numerous puffs in the computational domain.

Methodology

- ▶ A distributed computing solution is employed to access additional computing resources.
- ▶ Hive Grid is an intranet system developed by Lakes Environmental Inc. to harness idle processing cycles of all available personal computers in an organization (see Fig. 1).
- ▶ Distributed computing method requires the modelling task be divided into a series of monthly calculations for each source.
- ▶ As partial results from participating computers are returned, they are summed to yield the final total impact in post processing.
- ▶ Further reduction of computational effort is achieved through application of advanced modelling techniques.

MM5-CALMET

- ▶ NCAR/PSU Mesoscale Meteorological Model (MM5) is a numerical weather prediction model developed for regional weather forecasting.
- ▶ Air quality studies employ MM5 to reconstruct historical meteorological records.
- ▶ Lakes Environmental Inc. executes MM5 model to generate 5 years meteorological data for clients everywhere in the world. This includes 12-km MM5 data for the years 2000 to 2004 for U.K., Alberta (see Fig. 2), and southwestern Ontario.
- ▶ MM5 data is coupled to CALMET as initial guess field.
- ▶ CALMET interpolates the relatively coarse grid MM5 data into the finer computational grid of CALMET.
- ▶ CALMET creates topographical forced wind fields and embeds them into the interpolated field. The resultant field is balanced by minimizing the divergence.



Fig. 1: Lakes Environmental HIVE Grid Architecture

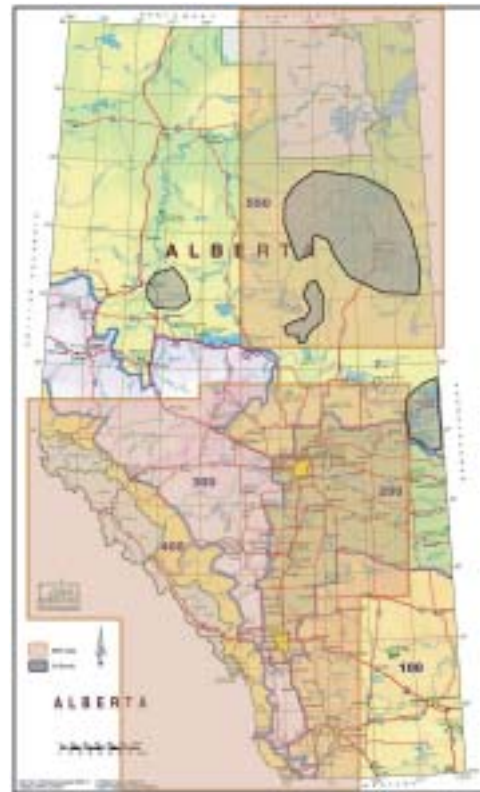


Fig. 2: Lakes Environmental prepared 12-km MM5 data for the years 2000 to 2004 (shaded area)

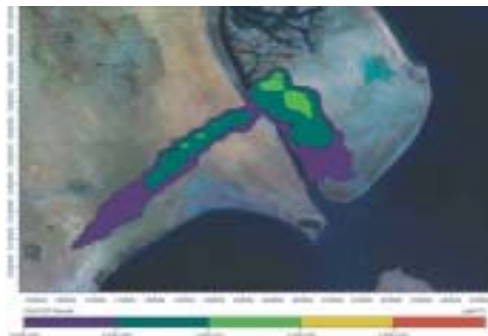


Fig. 3: Use of MM5-CALPUFF to simulate dispersion of pollutants for 1 day of period. Diurnal shift of coastal winds is evident from the diagram.



Fig. 4: SO₂ concentration from a 5-day simulation



Fig. 5: New SO₂ concentration when emission rate increases by 4 times

	VISB	SO ₂	SO ₄
1% S fuel	168	2.50E-4	1.52E-5
4% S fuel	640	9.90E-4	6.10E-5
Ratio	3.8	4.0	4.0
Adjusted for BG VISB (10 units)	4.0		

Table 1: Compare ratio of impacts from 4% Sulphur to 1% Sulphur fuels according to a 5-day simulation. Units are arbitrary.

"Best-Practices" Techniques

- ▶ This project utilizes CALSUM method and source scaling to reduce computations.
- ▶ Source grouping method can also reduce some calculations but it is not used.
- ▶ Judicious application of modelling techniques can drastically reduce CPU time (see Table 2), while achieving accurate modelling results.

CALSUM	Source Grouping*	Source Scaling	CPU Total
No	No	No	336 days
Yes	No	No	141 days
Yes	Only identical	No	130 days
Yes	Yes	No	71 days
Yes	No	Yes	21 days
Yes	Only identical	Yes	20 days
Yes	Yes	Yes	11 days

Table 2: Summary of computational processing requirements.

Key (*) – IWAQCM Phase 2 report suggested a source grouping method in which two nearby sources are combined as a single entity of average properties. It is an approximate method unless the two sources share identical properties (emission rates can be different though).

CALSUM Method

- ▶ Puffs are independent of each other in CALPUFF.
- ▶ Partial impacts from each source can be combined to yield the total impact due to all of the sources. Processor CALSUM has been developed to facilitate the summation (and scaling) process.

Advantage

- ▶ Each partial calculation requires less memory and shorter life span. These small jobs are more portable and conveniently executed by any desktop computers.
- ▶ Total impacts due to existing sources are computed for once. Incremental impacts due to new sources are superimposed to the old impact to yield the final total.

Source Scaling

- ▶ Source scaling can significantly reduce repeated calculations. However, this method requires that impacts are linearly proportional to the source strength, which is true if the following conditions prevail:
 - ▶ No chemical transformation is modelled; or
 - ▶ The chemical transformation is (approximately) linear
- ▶ For emission with only sulphur dioxide, the nonlinearity of chemical transformation is unimportant (see Figs. 4, 5 and Table 1).

Conclusion

By application of this innovative distributed computing solution and the "best-practice" modelling techniques for CALPUFF, Lakes Environmental completed all the calculations in one month instead of one year.