RECENT APPLICATIONS OF MM5, SMOKE, AND CMAQ IN CANADA

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1.0 INTRODUCTION

The RWDI Group of Companies (RWDI) have been involved in a number of regional-scale air quality modelling applications since the last "Models-3 Workshop" (see: Boulton *et al.*, 2000). RWDI has been retained by groups such as the Government of Hong Kong, Canadian Federal, Provincial, and Municipal governments, and private industry to perform all manner of regional air quality studies.

These projects have covered a variety of geographic regions (e.g., southern China and Hong Kong, the northeastern U.S. and southeastern Canada, and central and western Canada), and have involved a number of different models and modelling systems, including the Hong Kong Environmental Protection Department's PATH model framework (Boulton *et al.*, 2001), as well as with the US EPA's Models-3 Framework. Although sometimes run through their respective GUI Frameworks, these models are typically run in stand-alone or script mode.

Some of the models being used by RWDI in recent years include those for replicating: regional-scale meteorological phenomena (MM5, MC2); natural and man-made emissions (MEPPS, EMS-95, SMOKE); and, atmospheric chemistry and transport (SAQM, CMAQ). RWDI currently supports these and other models on a variety of computing platforms, including: Windows NT/2000, LINUX, SUN, and SGI and, to our knowledge, is the only group supporting MM5, SMOKE, and CMAQ all on the Windows platform.

The focus of this paper is on recent applications of MM5, SMOKE, and CMAQ in Canada.

2.0 METEOROLOGY MODELLING WITH MM5

RWDI has been involved in studies involving all aspects of meteorological modelling, including: the preparation of inputs and running of model pre-processors such as FDDA, running MM5 itself, performing sensitivity tests, post processing model outputs, and undertaking detailed qualitative and quantitative analyses.

Over the past several years, RWDI has performed sensitivity tests under different synoptic conditions and have evaluated the impacts attributed to different combinations of boundary layer schemes, micro-physics options, cloud and convective schemes, FDDA techniques, etc.

Over the past three years, MM5 modelling in support of emission and atmospheric transport and chemistry modelling has been performed over the following domains and episodes:

1) northeastern U.S. and southeastern Canada
   a) 36, 12, and 4-km grid spacing for July, 1995
   b) 36, 12, and 4-km grid spacing for July, 1999
   c) expanded 36-km domain for July, 1999
   d) expanded 36-km domain for August, 2001

2) western Canada and Alberta
   a) 36, 12, and 4-km grid spacing for August, 2001

In collaboration with the University of British Columbia, RWDI is adopting meteorological fields produced using Environment Canada's MC2 meso-scale meteorological model for input to MCIP2, and hence SMOKE and CMAQ. This project, being funded by Environment Canada, is part of a cross-border, International Air Quality Modelling Project initiative involving a number of agencies including: the Washington State Department of Ecology, Washington State University, the Greater Vancouver Regional District, and the National Research Council of Canada. This work will represent the first time that MC2 has been used as a meteorological pre-processor for Models-3.

Sensitivity tests and detailed model evaluations have been performed involving both quantitative and qualitative techniques. The results of some of these tests and their associated impacts on air quality model results have proven to be very important(e.g., cloud prediction) as discussed in greater detail elsewhere (Qiu and Lepage, 2002).

3.0 EMISSION INVENTORY PROCESSING WITH SMOKE

Emission processing is complex and usually involves preparing a large number of model-specific inputs and running a wide variety of pre-processors. SMOKE is no exception. RWDI has been involved in a number of projects performing not only SMOKE runs, but also preparing SMOKE inputs such as spatial surrogates and creating unique software utilities for the purpose of streamlining SMOKE processes. Studies involving SMOKE have ranged from relatively straight forward base-case and business-as-usual growth

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scenarios, to more complicated power plant emission displacement scenarios involving complex start-stop cycles and seasonal shifts in emission outputs (Lepage *et al.*, 2002).

RWDI has applied SMOKE as an emission processor in support of dozens of modelling applications over the northeastern U.S., southeastern Canada, western Canada and Alberta. In addition, RWDI has prepared spatial surrogates for SMOKE modelling applications on different domains, nested grids, and geographic projections.

3.1 Canadian Emission Inventory Data

RWDI has used various versions of the US EPA National Emission Inventory (NEI), as well as the Canadian 1995 Criteria Air Contaminant Emission Inventory. RWDI has used not only the area and mobile source components of the 1995 CAC inventory but, through confidentiality agreements with Environment Canada, has also incorporated the Canadian point source inventory and integrated these inputs into both MEPPS and SMOKE for various modelling applications (Qiu and Lepage, 2001).

Working with the Canadian emission data in SMOKE has required the creation of unique, "Canadianized" cross-reference files for spatial, speciation, and temporal factor allocations to account for unique SCC codes present in the Canadian emission inventory that are not incorporated in the SMOKE default cross-reference files.

3.2 Spatial Surrogates

The spatial surrogate file format required for input into SMOKE is relatively simple. Because of the flexibility within SMOKE to handle any number and type of spatial surrogates, a new approach to surrogate creation was developed. ESRI's ARCVIEW GIS software was selected over traditional software (i.e., ARC/INFO) to perform the overlay and surrogate calculation procedures. Scripts written in Avenue (the resident, object oriented programming language in ARCVIEW), allow for a simplified approach to calculating surrogate ratios by grid cell over a given domain (Boulton, *et al.*, 2002).

As part of this new approach, significant flexibility was added to the surrogate creation process. For example, the ability to use socio-economic and demographic parameters based on enumeration areas and census tracts using common geographic data (i.e., ARCVIEW shapefiles) was incorporated. In this way, many surrogates can be created in fewer steps using available census data, allowing for a more realistic representation of the location and spatial extent of emission sources.

Based on this approach, RWDI has produced more than 20 unique spatial surrogates for allocating emission data to model grids across most of Canada.

3.3 SMOKE Utilities

Under contract for Environment Canada, RWDI developed two unique software tools, namely "SMOKE-In" and "EI-View", for processing Canadian emission inventory data for input into SMOKE. SMOKE-In is a Microsoft ACCESS database application with built-in routines and GUI menus for importing emission data from SMOKE-ready (IDA ASCII) files and Canadian NET database (.dbf) files. Once imported, the relational database engine within ACCESS can be used to perform queries, sorts, filters, etc. on the emission data. These features allow the data to be analyzed and QA'ed efficiently and effectively by someone not necessarily familiar with SMOKE, but with a basic knowledge of common database functions. Utilities have also been developed for applying growth factors, creating reports, and exporting data for input to EI-View. Once the data have been manipulated, etc. they can be output from SMOKE-In as SMOKE-Ready IDA ASCII files.

EI-View is a graphic presentation utility written as an extension to ARCVIEW that can be used to display emission tables produced from SMOKE-In either at a county-wide level, or as gridded emissions based on one of the available spatial surrogates developed as part of the same project. The grid resolution for this study was 4-km, and the domain extended from British Columbia, all the way through to eastern Ontario. Figure 1 is a sample plot produced using SMOKE-In and EI-View that depicts annual emissions of NO_x across the southern half of western Canada attributed to on-road vehicle emissions, apportioned to a spatial surrogate representing major roads.

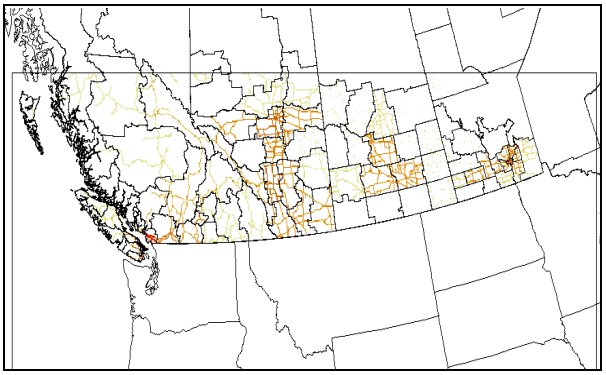

Figure 1. Annual NO_x emissions from on-road vehicles apportioned to major roads

4.0 ATMOSPHERIC CHEMISTRY AND TRANSPORT MODELLING WITH CMAQ

Outputs from atmospheric transport and chemistry models such as CMAQ can provide us with an indication of past, present, and future air quality over a range of time periods and large geographic areas.

RWDI has participated in a number of recent studies requiring CMAQ runs over nested domains for the purpose of investigating the effects on air quality related to impending government legislation and emission control scenarios. Similar qualitative and quantitative techniques to those used to evaluate the meteorological mode outputs have been adopted for evaluation of the CMAQ model results. Although fairly complex and involved, CMAQ has proven to be useful for assessing regional-scale air quality impacts attributed to large industrial facilities (Lepage *et al.*, 2002.

Sensitivity tests with CMAQ inputs have proven the importance of sufficient spin-up time, vertical and horizontal grid resolutions, and the assignment of realistic initial and boundary conditions.

5.0 OTHER ACTIVITIES IN CANADA

RWDI is the only Canadian private company currently offering the Models-3 suite of models as a service in support of government and private industry modelling initiatives. Other Canadian groups currently using the MM5, SMOKE, and CMAQ suite of models include: the National Research Council (NRC) of Canada, the Ontario Ministry of the Environment (MOE), a research group at the University of Waterloo Centre for Atmospheric Sciences, and several groups within Environment Canada including the Pacific and Yukon Region, the Prairie and Northern Region, the Meteorological Services of Canada (MSC).

6.0 CONCLUSIONS

Over the past several years, RWDI has used the Models-3 suite of models in a variety of applications across the heavily populated regions of Canada. Different government agencies have adopted these models for both proof of concept / benchmark and emission scenario modelling, and science assessment and model development applications. To date, there have been few applications for private industry.

RWDI has played a lead role in the practical application of Models-3 in Canada, and has provided support to research groups by providing various services pertaining to different aspects of the modelling, from performing individual model runs and data preparation for modelling, to full-scale modelling applications.

7.0 REFERENCES

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