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Chapter 27

Air Quality Modeling Resources on the Web

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Abstract: This chapter presents a list of web addresses of useful sites for scientists, engineers, and managers using or developing air quality models.

Key Words: Air quality modeling, Internet sites, regulatory models, available software, courses online.

1 Introduction

The Internet revolution during the last 15 years has caused enormous progress in sharing data and information worldwide. The resources available on the Web today are enormous, and it is practically unthinkable, for a scientist, to work without this tool. However, some problems still remain. For example, 1) it is not always easy to identify the best and most reliable sources of information; 2) important sites often change address; and 3) the enormous amount of information on the web often provides a distraction more than a solid scientific support.

Nevertheless, the Internet revolution has changed scientists' lives - ways of operating, performing research and development studies. This has been particularly true for environmental sciences, in general, and air quality modeling, in particular.

This chapter presents a semi-organized list of topics and internet addresses that may be particularly useful to scientists, engineers, and managers using or

developing air quality models. The list is certainly incomplete and should be regarded like a collection of examples, more than a comprehensive catalog ; but in spite of its limitation, it represents a good starting point, especially for a researcher at the beginning or intermediate stage of his exploration of the world of air quality modeling.

Readers are encouraged to provide new Hyperlinks by contacting the author via email. All valuable suggestions will be included in possible future volumes.

2 Regulatory Issues

Title: Support Center for Regulatory Atmospheric Modeling (SCRAM)
Owner: US Environmental Protection Agency
Summary: This website is maintained by EPA's Air Quality Modeling Group (AQMG). The AQMG conducts modeling analyses to support policy and regulatory decisions in the Office of Air and Radiation (OAR) and provides leadership and direction on the full range of air quality models and other mathematical simulation techniques used in assessing control strategies and source impacts. Documentation and guidance for these air quality models can be found on this website, including downloadable computer code, input data, and model processors.
Hyperlink: http://www.epa.gov/scram001/ and
http://www.epa.gov/ttn/scram/guidanceindex.htm

Title: Atmospheric Sciences Modeling Division (ASMD)
Owner: NOAA's Air Resources Laboratory (ARL) and US Environmental Protection Agency
Summary: ASMD implements the Memorandum of Understanding (MOU) and Memorandum of Agreement (MOA) between the Department of Commerce (DOC) and EPA, develops and evaluates predictive atmospheric models on all spatial and temporal scales for forecasting the Nation's air quality, and for assessing changes in air quality and air pollutant exposures, as affected by changes in ecosystem management and regulatory decisions. ASMD is responsible for providing a sound scientific and technical basis for regulatory policies to improve ambient air quality. The models developed by ASMD are being used by EPA, NOAA, and the air pollution community in understanding and forecasting not only the magnitude of the air pollution problem, but also in developing emission control policies and regulations.
Hyperlink: http://www.epa.gov/asmdnerl/

Title: Models Knowledge Base (KBase)
Owner: EPA's Council for Regulatory Environmental Modeling (CREM)
Summary: The CREM's Draft Guidance for Environmental Models provides recommendations for model development, evaluation, and application. The Models Knowledge Base is intended to be a living demonstration of the

recommendations from the Guidance for Environmental Models. In this way, these two products work in tandem to describe and document good modeling practices.
Hyperlink: http://cfpub.epa.gov/crem/knowledge_base/knowbase.cfm#overview

Title: National Exposure Research Laboratory (NERL)
Owner: US Environmental Protection Agency
Summary: National Exposure Research Laboratory (NERL) is comprised of several divisions with diversified research specialties. NERL conducts research and development that leads to improved methods, measurements and models to assess and predict exposures of humans and ecosystems to harmful pollutants and other conditions in air, water, soil, and food.
Hyperlink: http://www.epa.gov/nerl/

Title: Air Quality Modelling
Owner: Alberta Environment
Summary: Air dispersion modelling is a method of predicting the ground level concentration and deposition of air pollutants from one or more sources. The method may include relationships between emissions and air quality that incorporates the transport, dispersion and transformation of compounds emitted into the air.
Hyperlink: http://www3.gov.ab.ca/env/air/AQModelling/index.html

Title: California Air Resources Board
Owner: State of California
Summary: Collection of modeling software and some associated documentation
Hyperlink: http://www.arb.ca.gov/html/soft.htm#modeling

Title: Air Quality Assessment Division – Department of Environmental Quality (DEQ) Louisiana
Owner: State of Louisiana
Summary: The Air Quality Assessment Division manages a number of activities in support of the overall air program for the state.
Hyperlink: http://www.deq.louisiana.gov/portal/tabid/2457/Default.aspx

Title: UK Dispersion Modelling Bureau
Owner: UK Met Office
Summary: The UK Dispersion Modelling Bureau is part of the Met Office (originally an abbreviation for Meteorological Office, but now the official name in itself) which is the UK's national weather and meteorological service. The meteorologists in the bureau are among the UK's leading experts in areas such as:

- meteorology
- air quality studies and forecasting
- air pollution dispersion modelling
- industrial emissions

Hyperlink: http://www.metoffice.gov.uk/

3 Books

Title: Fundamentals of Stack Gas Dispersion
Author(s) : Milton R. Beychok
Summary: This is the new, fourth edition of the book on dispersion modeling of continuous, buoyant air pollution plumes which takes nothing for granted. Every equation is completely derived step-by-step without any complicated or advanced mathematics. Every constraint and assumption is fully explained. A set of self-study exercises is also included with the book.
Hyperlink: http://www.air-dispersion.com/

Title: Air Quality Modeling – Book Series
Author(s): Paolo Zannetti et al.
Summary: The EnviroComp Institute and the Air & Waste Management Association have joined forces to publish a new book series on air quality modeling, both traditional print and electronic formats. The first volume was published in December 2003. The second volume has been published in August 2005. And the third volume is expected to be published in late 2007.
Hyperlink: http://www.envirocomp.org/aqm/

Title: Air pollution dispersion modeling books
Author(s): Wikipedia
Summary: The information listed below for each of the **air pollution dispersion modeling books** includes the author(s), the publication date, the title, the edition, by whom published, and the ISBN or ISSN where available. The list is organized into two categories. One category is entitled "Books" and defined as books written by no more than three authors. The other category is entitled "Proceedings" and defined as books or other publications which are the proceedings of technical conferences or workshops.
Hyperlink:
http://en.wikipedia.org/wiki/Air_pollution_dispersion_modeling_books

4 Available Software

Title: Support Center for Regulatory Atmospheric Modeling (SCRAM)
Owner: US Environmental Protection Agency

Summary: This website is maintained by EPA's Air Quality Modeling Group (AQMG). The AQMG conducts modeling analyses to support policy and regulatory decisions in the Office of Air and Radiation (OAR) and provides leadership and direction on the full range of air quality models and other mathematical simulation techniques used in assessing control strategies and source impacts. Documentation and guidance for these air quality models can be found on this website, including downloadable computer code, input data, and model processors.
Hyperlink: http://www.epa.gov/scram001/

Title: Software - Utilities and Modeling
Owner: California Air Resources Board
Summary: This page presents software and documentation available via the California Air Resources Board Information System (CARBIS).
Hyperlink: http://www.arb.ca.gov/html/soft.htm

Title: U.S. EPA Models
Owner: Lakes Environmental
Summary: U.S. EPA Models - Download EPA's Most Used Air Quality Models - MODELS, DOCUMENTATION, AND GUIDELINES
Hyperlink: http://www.weblakes.com/lakeepa1.html

Title: The GAIA Model Base
Owner: GAIA: A Multi-Media Tool for Natural Resources Management and Environmental Education.
Summary: Air quality simulation models
Hyperlink: http://www.ess.co.at/GAIA/models/aria.htm

Title: Air Pollution Software
Owner: Scientific Software Group
Summary: Air Pollution Software
Hyperlink: http://www.scisoftware.com/environmental_software/index.php?cPath=25

Title: CALPUFF Modeling System
Owner: Atmospheric Studies Group
Summary: CALPUFF is an advanced non-steady-state meteorological and air quality modeling system developed by ASG scientists. It is maintained by the model developers and distributed by TRC. The model has been adopted by the U.S. Environmental Protection Agency (U.S. EPA) in its *Guideline on Air Quality Models* as the preferred model for assessing long range transport of pollutants and their impacts on Federal Class I areas and on a case-by-case basis for certain near-field applications involving complex meteorological conditions. The modeling system consists of three main components and a set of preprocessing and postprocessing programs. The main components of the modeling system are CALMET (a diagnostic 3-dimensional meteorological model), CALPUFF (an air quality dispersion model), and CALPOST (a postprocessing package). Each of

these programs has a graphical user interface (GUI). In addition to these components, there are numerous other processors that may be used to prepare geophysical (land use and terrain) data in many standard formats, meteorological data (surface, upper air, precipitation, and buoy data), and interfaces to other models such as the Penn State/NCAR Mesoscale Model (MM5), the National Centers for Environmental Prediction (NCEP) Eta model and the RAMS meteorological model.
Hyperlink: http://www.src.com/calpuff/calpuff1.htm

Title: Air Quality Modeling
Owner: South Coast Air Quality Management District
Summary: The following models are available to assist the CEQA practitioner in calculating impact to air quality. The following links will take you directly to these models located on other websites.
Hyperlink: http://www.aqmd.gov/CEQA/models.html

Title: MM5
Owner: Penn State University and National Center for Atmospheric Research
Summary: The PSU/NCAR mesoscale model (known as MM5) is a limited-area, nonhydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale atmospheric circulation. The model is supported by several pre- and post-processing programs, which are referred to collectively as the MM5 modeling system. The MM5 modeling system software is mostly written in Fortran, and has been developed at Penn State and NCAR as a community mesoscale model with contributions from users worldwide.
Hyperlink: http://www.mmm.ucar.edu/mm5/mm5-home.html

Title: Compilation of atmospheric dispersion models
Hyperlink:
http://en.wikipedia.org/wiki/Compilation_of_atmospheric_dispersion_models

Title: Selected Environmental and Biological Models
Hyperlink: http://erda.rutgers.edu/resources/resources1.php

Title: Polyphemus
Owner: Multiple Groups
Summary: Polyphemus is a Cyclops in Odyssey http://en.wikipedia.org/wiki/Polyphemus whose name roughly means "multiple speeches". It is consistent with the goals of the system, that is, gathering on the same platform:

- several models: with Gaussian, Eulerian, ... formulations;
- several scales: from small/local scale to continental scale; multiple polluants: passive, radionuclides, photochemistry, aerosols, POP, ...
- processing from many inputs (meteorological models, ground data);
- many advanced methods: data assimilation, ensemble forecasting, models coupling, ...

It is written as much as possible with modern computer languages (mainly C++), and only perennial and scalable developments are included. Polyphemus is open. It is open source, distributed under GNU GPL, well documented (for users and developers), and released on a regular basis. Open also means that contributions from other teams are welcome.
Hyperlink: http://cerea.enpc.fr/polyphemus/introduction.html and http://www.atmos-chem-phys-discuss.net/7/6459/2007/acpd-7-6459-2007.html

Title: MERLIN (Multi-Pollutant Multi-Effect Modeling of European AiR Pollution ControL Strategies - an INtegrated Approach).
Owner: Cluster of European Air Quality Research (CLEAR)
Summary: The aim of this proposed project is the development of a computer-based model system to determine the bundle of air pollution control measures, that is capable of achieving compliance with air quality limit and target values (for emission, concentrations and deposition) for specific pollutants at least-costs. Furthermore, the model will be used to calculate benefits, i.e. avoided damage costs by implementing air pollution control measures, first in a physical way, and in a second step - as far as possible - in monetary terms. Thus, costs and benefits of different bundles of measures can be estimated and cost-benefit analysis can be applied. In addition, macroeconomic effects and distributional impacts of pollution control strategies are determined.
Hyperlink: http://www.merlin-project.de/

5 Dispersion Models

Title: Dispersion Modeling
Owner: US Environmental Protection Agency
Summary: Dispersion modeling uses mathematical formulations to characterize the atmospheric processes that disperse a pollutant emitted by a source. Based on emissions and meteorological inputs, a dispersion model can be used to predict concentrations at selected downwind receptor locations.
Hyperlink: http://www.epa.gov/scram001/dispersionindex.htm

Title: The Air Pollution Model (TAPM) Technical descriptions and pricelist
Owner: CSIRO
Summary: The Air Pollution Model (TAPM) is a software package developed by CSIRO to estimate the spread and impact of air pollution. TAPM is a meteorological, prognostic air pollution model.
Hyperlink: http://www.cmar.csiro.au/research/tapm/

6 Photochemical Models

Title: Photochemical Modeling
Owner: US Environmental Protection Agency
Summary: Photochemical air quality models have become widely recognized and routinely utilized tools for regulatory analysis and attainment demonstrations by assessing the effectiveness of control strategies. These photochemical models are large-scale air quality models that simulate the changes of pollutant concentrations in the atmosphere using a set of mathematical equations characterizing the chemical and physical processes in the atmosphere. These models are applied at multiple spatial scales from local, regional, national, and global.
Hyperlink: http://www.epa.gov/scram001/photochemicalindex.htm

Title: CAMx
Owner: Environ
Summary: The Comprehensive Air quality Model with extensions is a publicly available open-source computer modeling system for the integrated assessment of gaseous and particulate air pollution. Built on today's understanding that air quality issues are complex, interrelated, and reach beyond the urban scale, CAMx is designed to:

* Simulate air quality over many geographic scales
* Treat a wide variety of inert and chemically active pollutants:
    - Ozone
    - Inorganic and organic PM2.5/PM10
    - Mercury and toxics
* Provide source-receptor, sensitivity, and process analyses
* Be computationally efficient and easy to use

Hyperlink: http://www.camx.com/

Title: EKMA/OZIP
Owner: The Shodor Education Foundation, Inc.
Summary: This exercise was designed for environmental professionals and educators by scientists and instructional design educators at the Shodor Education Foundation, Inc., in cooperation with the North Carolina Supercomputing Center and the North Carolina Industrial Extension Service (North Carolina State University). This project is being conducted under EPA Cooperative Agreement CR 822080 awarded to the Industrial Extension Service, North Carolina State University, with the North Carolina Supercomputing Center as the main technical partner. It represents the first step in a process of determining and recommending a comprehensive modeling curriculum which could be implemented by EPA through the Air Pollution Training Institute, by state and local agencies, and by universities.
Hyperlink: http://www.shodor.org/ekma/

Title: Air quality modeling in PREV'AIR
Owner: The Pierre-Simon Laplace Institute of the Centre National de Recherche Scientifique (IPSL/CNRS) and the INERIS for the CHIMERE Model, and Centre National de Recherches Météorologiques de Météo France (CNRM/Météo France) for the MOCAGE model
Summary: The three-day forecasts and air quality maps published on a daily basis on the PREV'AIR server are the result of numerical simulations carried out with the help of so-called 3D eulerian deterministic models ("chemistry-transport" models). For periods of time ranging from several days to several months, these tools allow to calculate changes in photochemical and specific pollution in the lower layer of the atmosphere, on different spatial scales.
Hyperlink: http://prevair.ineris.fr/en/modele.php

Title: Models-3/Community Multiscale Air Quality (CMAQ)
Owner: Community Modeling & Analysis System
Summary: The latest version of the Community Multi-scale Air Quality (CMAQ) model has capabilities for conducting urban to regional scale simulations of multiple air quality issues, including tropospheric ozone, fine particles, toxics, acid deposition, and visibility degradation. The primary goals for the Models-3/Community Multiscale Air Quality (CMAQ) modeling system are to improve:

1. the environmental management community's ability to evaluate the impact of air quality management practices for multiple pollutants at multiple scales
2. the scientist's ability to better probe, understand, and simulate chemical and physical interactions in the atmosphere

Hyperlink: http://www.cmascenter.org/

Title: Regional Modeling System for Aerosols and Deposition (REMSAD)
Owner: ICF International/Systems Applications International
Summary: Developed by ICF International/Systems Applications International to support a better understanding of the distributions, sources, and removal processes relevant to regional haze, particulate matter and other airborne pollutants, including soluble acidic components and toxics. REMSAD includes the streamlined micro-CB gas-phase chemical mechanism and an efficient transport algorithm that allow continental scale simulations of full calendar years. REMSAD provides spatially and temporally resolved air concentrations and (wet and dry) deposition values. Recent improvements to the modeling system include expanded treatment of mercury chemistry, the addition of a detailed secondary organic aerosol (SOA) treatment and improved performance under stagnant meteorological conditions. REMSAD calculates the concentrations of both inert and chemically reactive pollutants by simulating the atmospheric processes that affect pollutant concentrations over regional scales. It includes processes relevant to regional haze, particulate matter and other airborne pollutants, including soluble acidic components and mercury.
Hyperlink: http://remsad.saintl.com/

Title: Urban Airshed Model (UAM)
Owner: Sonoma Technology Inc.
Summary: The UAM is a 3-D grid model designed to calculate the concentrations of both inert and chemically reactive pollutants by simulating physical and chemical processes that take place in the atmosphere.

- The UAM uses a mass balance in which relevant emissions, transport, chemical reaction, and removal processes are expressed in mathematical terms.
- Simulations are usually 24- to 72-hour periods during which episodic meteorological conditions persist.
- Typical UAM application:
  - Select episode (usually widespread exceedance of ozone NAAQS, typical meteorological conditions).
  - Select modeling domain to encompass ozone monitors that reported exceedances and all major source regions.
  - Prepare model inputs using observed meteorological, emission, and air quality data for an episode.
  - Evaluate model performance.
- The UAM is used for analysis of spatially and/or temporally differentiated future emission control strategies and their effect on air quality in various parts of the modeling region.

Hyperlink: http://epa.gov/oar/oaqps/pams/analysis/uam/uam.html

7 Receptor Models

Title: Receptor Modeling
Owner: US Environmental Protection Agency
Summary: Receptor models are mathematical or statistical procedures for identifying and quantifying the sources of air pollutants at a receptor location. Unlike photochemical and dispersion air quality models, receptor models do not use pollutant emissions, meteorological data and chemical transformation mechanisms to estimate the contribution of sources to receptor concentrations. Instead, receptor models use the chemical and physical characteristics of gases and particles measured at source and receptor to both identify the presence of and to quantify source contributions to receptor concentrations.
Hyperlink: http://www.epa.gov/scram001/receptorindex.htm

Title: EPA Unmix receptor model
Owner: US Environmental Protection Agency
Summary: The EPA Unmix receptor model was developed under this project. Unmix is named for its function, which is to "unmix" the concentrations of chemical species measured in the ambient air to identify the contributing sources. The particular mathematical approach used by Unmix is based on a form of Factor Analysis, but its novelty is that physically-meaningful constraints are

imposed which are intended to remove the undesirable ambiguity of the multiple solutions that are characteristic of ordinary Factor Analysis. For a given selection of species, Unmix estimates the number of sources, the source compositions, and source contributions to each sample. Chemical profiles of the sources are not required, but instead are generated from the ambient data.
Hyperlink: http://www.epa.gov/nerl/research/2004/g1-6.html

8 Air Quality Forecast and Resources

Title: Regional Air Quality Modeling Systems
Owner: NASA Langley Research Center
Summary: Scientists use the Regional Air Quality Modeling System (RAQMS) computer model to predict air quality around the globe. RAQMS has been designed to address the atmospheric chemistry modeling needs for NASA's Earth Science Enterprise science missions and to prototype future NASA, National Oceanic and Atmospheric Administration (NOAA), and Environmental Protection Agency (EPA) operational air quality prediction systems. It is a portable, global to regional scale meteorological and chemical computer modeling system. RAQMS assimilates remote and in-situ observations of atmospheric chemical composition to predict the distribution of atmospheric trace gases (air quality) within any region of the Earth. The Global Climate and Environmental Quality area of Langley's Creativity and Innovation initiative supports RAQMS.
Hyperlink: http://asd-www.larc.nasa.gov/new_AtSC/raqms.html

Title: FLEXTRA and FLEXPART
Owner: Andreas Stohl
Summary: FLEXTRA and FLEXPART are an atmospheric trajectory and a particle dispersion model, respectively, that are used by a growing user community. A recent user survey resulted in 34 groups from 17 countries who have confirmed to actively use one of the models for a variety of research purposes. There are also a few operational installations for emergency preparedness and similar objectives.
Hyperlink: http://zardoz.nilu.no/~andreas/flextra+flexpart.html

Title: AIRNow
Owner: U.S. EPA, NOAA, NPS, tribal, state, and local agencies
Summary: The U.S. EPA, NOAA, NPS, tribal, state, and local agencies developed the AIRNow Web site to provide the public with easy access to national air quality information. The Web site offers daily AQI forecasts as well as real-time AQI conditions for over 300 cities across the US, and provides links to more detailed State and local air quality Web sites.
Hyperlink: http://airnow.gov/

Title: International Air Quality

Owner: AIRNow
Summary: Air Quality information for various countries
Hyperlink: http://cfpub.epa.gov/airnow/index.cfm?action=where.world

Title: Atmospheric Pollution and Economic Development (APD)
Owner: IIASA
Summary: IIASA's work brings together geo-physical and economic aspects of pollution control into one assessment framework and implement it – together with a network of collaborators - for practical policy analyses in different regions of the world.
Hyperlink: http://www.iiasa.ac.at/rains/

Title: Experimental Chemical Weather Forecast over Italy
Owner: University of L'Aquila, Italy - CETEMPS
Summary: The system for the forecast of regional air quality relies on two main elements: a meteorological mesoscale model (the PennState/NCAR MM5 model) and a regional chemistry-transport model (CHIMERE model).

MM5 model is developed at the Pennsylvania State University and at the National Center for Atmospheric Research and is available for free. The meteorological model provides input data such as winds, temperature and humidity necessary to run the model of transport and chemistry. The meteo model is forced by daily ECMWF forecast and run on a grid with a horizontal resolution of 30 km.

The forecast of the evolution and transformation of chemical species is provided by the CHIMERE model. CHIMERE is developed in Paris (France) by a number of French institutions: Institut Pierre-Simon Laplace, C.N.R.S., INERIS, LISA (C.N.R.S.). It is a free software available under the GNU General Public License.

Everyday a 72h run is performed starting at h 12:00 of the previous day. The MM5 meteo model is run first and then its output is used by the chemical model CHIMERE to predict pollutant levels over Italy and surroundings. At the end of the simulation process another automatic procedure updates the figures visible on this web site.
Hyperlink: http://pumpkin.aquila.infn.it/forechem/

9 Visibility Modeling

Title: VISTAS Phase I Regional Haze Modeling
Owner: University of California, Riverside
Summary: The Clean Air Act establishes special goals for protection of visibility in many national parks and wilderness areas. Through the 1977 amendments to the Clean Air Act (CAA), Congress set a national goal for visibility as "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from

manmade air pollution". The Clean Air Act defines mandatory Class I Federal areas as national parks (over 6000 acres), wilderness areas (over 5000 acres), national memorial parks (over 5000 acres), and international parks that were in existence as of August 1977. The CAA requires that natural visibility conditions be attained in Class I areas by 2064, and also establishes certain requirements for making progress toward attainment at that date. States and tribes have authority under the CAA to develop State and Tribal Implementation Plans (SIPs and TIPs) to attain the CAA visibility standards for these Class I Areas.
Hyperlink: http://pah.cert.ucr.edu/vistas/

Title: Plume Visibility Model (PLUVUE II)
Owner: National Technical Information Service
Summary: PLUVUE is a visibility model designed to predict transport, atmospheric diffusion, chemical conversion, optical effects, and surface deposition of point-source emissions. PLUVUE performs plume optics calculations in two modes. In the Plume-based mode, the visual effects are calculated for a variety of lines of sight and observer locations relative to the plume parcel; in the observer-based mode, the observer position is fixed and visual effects are calculated for the specific geometry defined by the positions of the observer, plume, and sun.
Hyperlink: http://www.ntis.gov/products/bestsellers/cpn0041.asp?loc=4-2-0 or http://iaspub.epa.gov/edr/edr_proc_qry.navigate?P_LIST_OPTION_CD=CSDIS&P_REG_AUTH_IDENTIFIER=1&P_DATA_IDENTIFIER=90366&P_VERSION=1

10 Publications and Information Online

Title: Finding Air Quality Information on the Internet
Author(s): Envirometrics
Summary: This article is intended to provide a summary of the more useful air quality directory sites (i.e., sites with links to other sites) and sites with air quality information.
Hyperlink: http://www.envirometrics.com/news/main.html#search

Title: Uncertainty Analysis of Transport - Transformation Models (PhD dissertation)
Author(s): Sastry S. Isukapalli
Summary: Characterization of uncertainty associated with transport-transformation models is often of critical importance, as for example in cases where environmental and biological models are employed in risk assessment. However, uncertainty analysis using conventional methods such as standard Monte Carlo or Latin Hypercube Sampling may not be efficient, or even feasible, for complex, computationally demanding models.

This work introduces a computationally efficient alternative method for uncertainty propagation, the Stochastic Response Surface Method (SRSM). The SRSM approximates uncertainties in model outputs through a series expansion in normal random variables (polynomial chaos expansion). The unknown coefficients in series expansions are calculated using a limited number of model simulations. This method is analogous to approximation of a deterministic system by an algebraic response surface.

Further improvements in the computational efficiency of the SRSM are accomplished by coupling the SRSM with ADIFOR, which facilitates automatic calculation of partial derivatives in numerical models coded in Fortran. The coupled method, SRSM-ADIFOR, uses the model outputs and their derivatives to calculate the unknown coefficients.

The SRSM and the SRSM-ADIFOR are general methods, and are applicable to any model with random inputs. The SRSM has also been implemented as a black-box, web-based tool for facilitating its easy use.

The SRSM and the SRSM-ADIFOR have been applied to a set of environmental and biological models. In all the case studies, the SRSM required an order of magnitude fewer simulations compared to conventional methods, and the SRSM-ADIFOR required even fewer simulations. In addition to their computational efficiency, these methods directly provide sensitivity information and individual contributions of input uncertainties to output uncertainties; conventional methods require substantially larger numbers of simulations to provide such information. Thus, the SRSM and the SRSM-ADIFOR provide computationally efficient means for uncertainty and sensitivity analysis.

Finally, this research addresses uncertainties associated with model structure and resolution with application to photochemical air quality modeling. A three dimensional version of the regulatory Reactive Plume Model (RPM), RPM-3D, has been developed and applied to understand model uncertainty.
Hyperlink: http://www.ccl.rutgers.edu/~ssi/thesis/thesis.html

Title: GIS applications in air pollution modeling
Author(s): Niraj Sharma et al.
Summary: Motor vehicles have been closely identified with increasing air pollution levels in urban centers of the world (Mage et al, 1996; Mayer 1999). Besides substantial CO2 emissions, significant quantities of CO, HC, NOx, SPM and other air toxins are emitted from these motor vehicles in the atmosphere, causing serious environmental and health impacts. Like many other parts of the world, air pollution from motor vehicles is one of the most serious and rapidly growing problem in urban centers of India (UNEP/WHO, 1992; CSE, 1996; CRRI, 1998). The problem of air pollution has assumed serious proportions in some of the major metropolitan cities of India and vehicular emissions have been identified as one of the major contributors in the deteriorating air quality in these

urban centers (CPCB, 1999). Although, recently, improvement in air quality with reference to the criteria pollutants (viz. NOx, SO2, CO and HC) have been reported for some of the cities, the air pollution situation in most of the cities is still far from satisfactory (CPCB, 2000). The problem has further been compounded by the concentration of large number of vehicles and comparatively high motor vehicles to population ratios in these cities (CRRI, 1998).
Hyperlink:
http://www.gisdevelopment.net/application/environment/air/mi03220.htm

Title: Air Quality Modeling Appendix - Final Statewide Oil and Gas Environmental Impact Statement and Proposed Amendment of the Powder River and Billings Resource Management Plans
Author(s): U.S. Department of the Interior - Bureau of Land Management
Summary: Environmental Impact Statement
Hyperlink: http://www.mt.blm.gov/mcfo/cbm/eis/volume2/AirQualityApp.pdf

Title: Using a "Wiki" to pool experiences on atmospheric dispersion
Author(s): Helge Rørdam Olesen, National Environmental Research Institute, University of Aarhus, Denmark
Summary: A "Wiki" is a certain type of Web site that is especially suited for collaboration. It allows users to easily create and edit Web pages. A "Wiki" has a very open structure where anyone can contribute. Recently, a "Wiki" has been established on the subject of Atmospheric Dispersion Modelling. A "Wiki" is potentially a very powerful tool for the community of atmospheric dispersion professionals. A "Wiki" provides something that we normally miss in the community of atmospheric dispersion professionals: An easy possibility to provide feedback and pool our experiences with procedures, data sets and models related to our work.
Hyperlink: http://atmosphericdispersion.wikia.com

11 Courses Online

Title: Air Quality Modeling – AOSS 563
Author(s): Prof. Perry Samson
Summary: Design of effective strategies for managing atmospheric resources requires the use of computer models to simulate the transport, dispersion, chemistry and deposition of airborne pollutants on scales from a few meters to thousands of kilometers. This course introduces fundamentals of air pollution modeling with an emphasis on hands-on application to real-world situations.
Hyperlink: http://www.engin.umich.edu/class/aoss563/lectures/index.html

Title: Air Quality Meteorology

Author(s): A Developmental Course of the US Environmental Protection Agency in conjunction with the US National Oceanic and Atmospheric Administration - Developed by The Shodor Education Foundation, Inc.
Summary: This course is designed for environmental decision-makers, scientists, technical advisors, and educators by scientists and instructional design educators at the Shodor Education Foundation, Inc., North Carolina Supercomputing Center, and the North Carolina Industrial Extension Service (North Carolina State University).It represents the first step in a process of determining and recommending a comprehensive modeling curriculum which could be implemented by EPA through the Air Pollution Training Institute, by state and local agencies, and by universities.
Hyperlink: http://www.shodor.org/metweb/

Title: Basic Concepts in Environmental Sciences – **(**Module 6: Air Pollutants and Control Techniques)
Author(s): US EPA
Hyperlink: http://www.epa.gov/eogapti1/toc/full_toc.htm

12 Case Studies

Title: OMNI - Air Pollution Modelling in Practice
Author(s): The South East Institute of Public Health (SEIPH)
Summary: This 'Virtual Assessment Tool' is here to help those people who work in the field of air pollution. The site is specific to the area bounded by the M25 motorway, and provides assessment tools and information required by the National Air Quality Strategy (NAQS).
Hyperlink: http://www.seiph.umds.ac.uk/omni/frames/omniframe.htm

Title: Air quality in South East Queensland
Author(s): The Environmental Protection Agency (EPA), which includes the Queensland Parks and Wildlife Service (QPWS), is a department of the Queensland Government.
Summary: The South East Queensland Regional Air Quality Strategy notes that in addition to changing vehicle design, emissions can be greatly reduced by reformulating fuel types or substituting other types. On hot days, the pollutants created by petrol vapour evaporating into the atmosphere contribute significantly to smog development.
Hyperlink:
http://www.epa.qld.gov.au/environmental_management/air/air_quality_monitoring/air_quality_modelling/

Title: Fall line Air Quality Study (FAQS) Meteorology, Emissions, and & Air Quality Models
Author(s): Yongtao Hu and Ted Russell

Summary: The FAQS research team is using a system of meteorological, emissions, and air quality computer models (note 1) to characterize the major and minor factors that affect air quality in Augusta, Macon, and Columbus, Georgia. The models are used to study past episodes of poor air quality and to evaluate potential future actions that, if implemented, may reduce the incidence of air pollution and its associated impacts.
Hyperlink: http://cure.eas.gatech.edu/faqs/models/index.html

Title: Air Quality Modeling Report Snowmobile and Snowcoach Emissions
Author(s): Air Resource Specialists, Inc.
Summary: In support of the Winter Use Plan Preliminary Draft Environmental Impact Statement (PDEIS) for Yellowstone National Park (Yellowstone), Grand Teton National Park (Grand Teton), and the John D. Rockefeller, Jr. Memorial Parkway (Parkway), Air Resource Specialists, Inc. (ARS) completed an analysis of potential air quality impacts from snowmobile and snowcoach operations. This report analyzes potential air quality impacts for several preliminary alternatives utilizing air dispersion modeling and other accepted methods and models.
Hyperlink:
http://www.nps.gov/yell/parkmgmt/upload/final_air_quality_report_11_06.pdf

Title: Florida Department of Transportation (FDOT) Air Quality Modeling Plan
Author(s): A Florida Department of Transportation (FDOT)
Summary: The Florida Department of Transportation (FDOT) is truly a concerned partner in Florida's air quality. On-road highway emissions from motorized vehicles ranging from a one-hundred pound motor scooter to an eighty-thousand pound double-trailer truck produce substantial quantities of volatile organic compounds (VOCs) and nitrogen oxides (NOx). VOCs and NOx combine in the presence of sunlight to produce ozone.
Hyperlink: http://www.dot.state.fl.us/planning/systems/stm/aq.htm

Title: AIR POLLUTION MODELING AND APPLICATIONS IN ESTONIA
Author(s): Marko Kaasik and Veljo Kimmel
Summary: The modeling of air pollution in Estonia during Soviet Union period was complicated both due to ignorance of decision-makers and deficiency of good tools affecting also current situation.

Current practice is divided roughly into two parts: 1) official side relying on obsolete and not validated Russian models from the eighties not enabling to model most important polluter in cities - the traffic and 2) researcher side-dealing with development and use of advanced computers and new modeling tools.
Hyperlink: http://www.meteo.bg/EURASAP/39/marko.html

Title: Institute for Multi-dimensional Air Quality Studies.
Author(s): University oh Houston
Summary: We are a diverse group of researchers from fields of geosciences, math, computer science and chemistry committed to using premier scientific tools

to model the complex issues of air quality and climate change. Our modeling efforts address many critical components simultaneously including emissions inventories, meteorology, and atmospheric chemistry. We are currently developing atmospheric boundary layer measurement techniques. We work closely with national, state and local leaders to identify key scenarios to run on our modeling systems so that public policy is guided with the best science.
Hyperlink: http://www.imaqs.uh.edu/

13 Resources and lists of References

Title: Air pollution
Author(s): Wikipedia
Summary: Air pollution is a chemical, physical (e.g. particulate matter), or biological agent that modifies the natural characteristics of the atmosphere. The atmosphere is a complex, dynamic natural gaseous system that is essential to support life on planet Earth. Stratospheric ozone depletion due to air pollution has long been recognized as a threat to human health as well as to the Earth's ecosystems.

Worldwide air pollution is responsible for large numbers of deaths and cases of respiratory disease. Enforced air quality standards, like the Clean Air Act in the United States, have reduced the presence of some pollutants. While major stationary sources are often identified with air pollution, the greatest source of emissions is actually mobile sources, principally the automobile. Gases such as carbon dioxide, which contribute to global warming, have recently gained recognition as pollutants by some scientists. Others recognize the gas as being essential to life, and therefore incapable of being classed as a pollutant.
Hyperlink: http://en.wikipedia.org/wiki/Air_pollution

Title: Information about Air Quality Modeling
Author(s): Clean Air World - by The National Association of Clean Air Agencies (formerly STAPPA and ALAPCO)
Summary: Air Pollutants; Mercury and Other Toxic Air Pollutants; Ozone; Particle Pollution; Control Strategies; Mercury and Other Toxic Air Pollutants; Global Warming; Indoor Air Pollution; Measuring Air Pollution; Air Quality Modeling; Monitoring; Vehicles and Fuels; Cars, Trucks and Buses; Other Engines and Equipment
Hyperlink: http://www.cleanairworld.org/TopicLinks.asp#23

Title: Air Dispersion Modeling
Author(s): Open Directory Project
Summary: In the context of this "Air Dispersion Modeling" category, air dispersion models may be defined as computerized mathematical calculations for predicting the dispersion behavior of air pollutants emitted into the atmosphere.

Hyperlink:
http://dmoz.org/Science/Environment/Air_Quality/Air_Dispersion_Modeling/

Title: Convention on Long-range Transboundary Air Pollution
Author(s): UN Economic Commission for Europe
Summary: Since 1979 the Convention on Long-range Transboundary Air Pollution has addressed some of the major environmental problems of the UNECE region through scientific collaboration and policy negotiation. The Convention has been extended by eight protocols that identify specific measures to be taken by Parties to cut their emissions of air pollutants.
Hyperlink: http://www.unece.org/env/lrtap/welcome.html

14 Calculation Sites

Title: Air pollution model
Author(s): SouthWest Organizing Project
Summary: The air pollution model on this page is most popular for calculating the direction and rates that pollution will travel given weather, distance, and emission rates. The model is based on theories of statistical probability. The locations of particular chemical molecules are determined following a set of assumptions regarding weather, topographic features, characteristics of the various chemicals. This model works best for short term modeling. When looking at the long term, the model's results must be averaged to account for time.
Hyperlink: http://www.swop.net/intel/air_model.html

Title: Combustion Calculations Spreadsheets
Author(s): Envirometrics
Summary: These spreadsheets calculate sulfur dioxide, particulate matter, and chloride emissions by mass balance and nitrogen oxides from emission factors.
Hyperlink: http://www.envirometrics.com/news/main.html#calcs

Title: Odor Sampling Dilution Spreadsheets
Author(s): Envirometrics
Summary: If a sampled source has water content much higher than normal ambient humidity it may be necessary to dilute the sample with dry air to reduce the humidity and comply with the sampling protocols. This reduces condensation in the bag during shipment, which might adversely affect the measurement of the odor. A spreadsheet recently developed to compute the amount of pre-dilution dry nitrogen is available for downloading (about 20k).
Hyperlink: http://www.envirometrics.com/news/main.html#odorcalcs

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