

Annual Report 1998-99

National Research Center for Statistics and the Environment



NRCSE

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1. Summary

The third year of operation of NRCSE (Oct. 1, 1998 – Sep. 30, 1999) has been very productive. Two major workshops, on particulate matter air pollution ([sec. 2.3.2](#)), and on quality assurance of environmental models ([sec. 2.3.3](#)) have been held, with large attendance from a broad range of academic, private, and government scientists. The Center has had a rich visitors program ([sec. 3.2.1](#)), and a substantial number of papers, research reports, and presentations in a large variety of areas have been produced ([sec. 3.3](#), [Appendix B, C](#)). A program of outreach to EPA laboratories has been initiated ([sec. 2.3.1](#)). Several Center members have received national professional recognition ([sec. 2.5](#)). The Center has moved to a new location adjacent to the Statistics department ([sec. 4.5](#)). Outreach activities include seminars ([sec. 2.1](#), [Appendix A](#)), middle school curriculum development ([sec. 2.5](#)), and of course the Center web site <http://www.nrcse.washington.edu> ([sec. 2.2](#)). In order to broaden the base of the Center research, a number of subcontracts and joint projects have been initiated with different environmental statistics research groups in the United States, Canada, and Europe ([sec. 4.6](#)).

2. Outreach activities

2.1 Seminars

The seminar series during the academic year 1998-99 had a quarterly theme. In Autumn 98 the theme was particulate matter air pollution, while in Winter the theme was assessment of environmental and ecological models. The Spring quarter seminar series focused on student and post-doctoral researchers presenting their current work, and was carried out jointly with the graduate program on Quantitative Ecology and Resource Management. During Autumn and Winter all seminars were videotaped and made available on the world-wide web at URL <http://www.nrcse.washington.edu/seminars/nrcse-video.asp>.

The University has several weekly statistical seminar series. Consequently, there has been relatively sparse attendance at NRCSE seminar. A decision was made to limit the NRCSE seminars to three per quarter, and make them joint with other groups. During Autumn 99 the NRCSE seminars were joint with Statistics, Biostatistics, and Atmospheric Sciences. In addition to the seminars, the Center is planning afternoon workshops to cover in more depth areas of interest to Center members. These workshops will start in Winter quarter 2000.

2.2 Web site

The Center web pages, located at <http://www.nrcse.washington.edu>, are the main source of information about the Center. During the time period of this report there were 145,905 successful requests for pages from over 12 000 different hosts. On average, about 10 Mb of data were transferred per day. About 20% of the visitors came from .edu domains, 18%



from .com, and 10% from each of .net and .gov/.us domains. Germany, France and Canada were the leading non-US domains. About 20% of the hosts could not be identified. The most visited directory was the research directory, where project descriptions and research reports are stored. The highest demand was for Technical Report 15: "Meteorological Adjustment of Western Washington and Northwest Oregon Surface Ozone Observations with Investigation of Trends" by Joel H. Reynolds, Barnali Das, Paul D. Sampson and Peter Guttorp.

A discussion board has been initiated. It contains both password protected internal group discussions and publicly available bulletin boards. It received about 1200 hits during the year.

The Center is preparing a policy statement on software posting. It is our intent to provide software at no cost to the community, but we are also determined to provide reliable and easily testable products. We hope to be providing software on the web during the coming year.

2.3 Workshops

2.3.1 EPA Corvallis

The Center has initiated a series of workshops at various EPA locations intended to give EPA researchers a feel for the kind of research being conducted and to initiate new research contacts. The first of these workshops took place at the EPA laboratory in Corvallis, Oregon, on April 13, 1999. Ten Center members and graduate students participated in the workshop, giving seven talks to a fairly large audience (at most presentations 20-30 EPA and OSU researchers were present). The titles of the talks are found in Appendix D1.

2.3.2 Particulate matter air pollution

EPA promulgated revised air quality standards for particulate matter on July 18, 1997. At that time, President Clinton committed EPA to complete the next Particulate Matter NAAQS review within the five-year statutory period required by the Clean Air Act. Due to the time required to establish PM_{2.5} monitoring networks, determine whether or not a location is in or out of compliance with the standard(s), and, if out, to develop a State Implementation Plan (SIP) to achieve compliance, implementation of the revised regulations for particulate matter would not begin for approximately ten years, well after the next NAAQS review. Also in this time frame, Congress directed EPA to arrange to have the National Research Council (NRC) to conduct a study to identify research priorities relevant to setting regulatory standards for ambient particulate matter. NRC responded by forming the Committee on Research Priorities for Airborne Particulate Matter, which



quickly produced its first of four planned reports, Research Priorities for Airborne Particulate Matter: I. Immediate Priorities and a Long-Range Research Portfolio, referred to here as the NRC Report. Research Topic 10 of this report, Analysis and Measurement, deals almost exclusively with statistical issues.

Soon after the release of the NRC Report, NRCSE and the EPA Office of Research and Development decided to organize a workshop focused on Topic 10. With co-sponsorship from the National Institute of Statistical Sciences and the Health Effects Institute, the NRCSE/EPA Particulate Methodology Workshop was held October 19–22, 1998, at the University of Washington in Seattle. The objective of the workshop was to bring together an interdisciplinary group of statistical and other scientists to illuminate statistical issues articulated in or raised by Topic 10, to identify priority statistical research bearing upon these issues, and to organize interdisciplinary research projects on these topics, targeted for completion prior to the end of the second Particulate Matter NAAQS review. Twenty-five invited speakers, discussants, and session chairs participated together with 36 other attendees.

The workshop was organized around formal presentations and discussion covering measurement, atmospheric transport, and modeling of particulate matter; understanding and developing models of particulate matter exposure and health effects; particle transformation; source apportionment; regulatory issues; and new or enhanced statistical research questions and findings stemming from particulate matter studies. The detailed list of presentations and speakers can be found in Appendix D2. All presentations were videotaped and are available at the web (<http://www.nrcse.washington.edu/NRCSE/pm-workshop/default.asp>). The core of the Workshop was the deliberations of seven working groups meeting each afternoon. The 19 research questions raised under Topic 10 of the NRC Report were grouped under six headings for discussion: time series analysis; assessment of current epidemiological studies; exposure-response models; study design towards estimation of long and short term effects of exposure; study design and the effects of measurement error in health effects modeling; and space-time modeling and estimation methods for more accurate estimates of individual exposures to particulate air pollution. A seventh group addressed Case-Crossover Studies. Summary reports of the working group discussions are posted on the NRCSE discussion board at <http://www.nrcse.washington.edu/discus/default.htm>.

The NRCSE/EPA Workshop on Particulate Methodology raised meaningful issues regarding the role of statistical science in the study of particulate matter air pollution. Leaders from statistical and environmental science shared their expertise and concerns and appeared to benefit from the interaction. Continuing particulate matter work is described in sections 3.2.2 and 3.1.16.



2.3.3 Quality assurance of environmental models

Over the past decade the number of models constructed by EPA scientists has increased remarkably. Many models are used in policy development and environmental regulation. Increasingly models are constructed that simulate ecological and environmental processes. The complex structure of these models, and in some cases the limited data associated with them, has led to concerns about model assessment.

EPA responded to this concern by establishing a committee to produce a White Paper for the Science Policy Council “Nature and Scope of Issues on Adoption of Model Use Acceptability Guidance.” NRCSE was involved in writing this paper (sec. 2.6) and, as an outcome of its discussions and deliberations, a joint EPA/NRCSE workshop on Quality Assurance of Environmental Models was organized at the University of Washington September 7–10, 1999. Some 60 participants from universities, regulatory agencies and consulting firms listened to 17 presented papers and contributed to discussions in four different areas: Life cycles of models; Peer review of models; Very High Order Models; and Tool Chest for Model Assessment.

The papers read ranged through a wide spectrum of aspects of model assessment. Among the presenters the first day with theme “Defining the problems of Model Assessment and Quality Assurance” were Naomi Oreskes, UC San Diego; David Ford, University of Washington; Jan Rotmans, ICIS, Maastricht, The Netherlands; and Robin Dennis, EPA. The second day, on “Development of Methodological and Quantitative Techniques,” featured Andrea Saltelli, EC Joint Research Centre, Italy; Adrian Raftery, University of Washington; Tony O’Hagan, University of Sheffield, U.K.; Joel Reynolds, Alaska Department of Game and Fish; and Wendy Meiring, UC Santa Barbara. Among the third day speakers, on “Assurance of Models Used in Environmental Regulation,” were David Stanners, European Environment Agency; Tom Barnwell, EPA; Linda Kirkland, EPA; and Helen Dawson, EPA. A detailed list of talks can be found in Appendix D3.

All presentations were videotaped, and will be available on the NRCSE web page (<http://www.nrcse.washington.edu/events/qaem/qaem.asp>). In addition, summaries of the discussion groups are available at <http://www.nrcse.washington.edu/discus/messages/70/109.html?MondaySeptember2719991009am>

2.4 Conference presentations

A number of Center members and graduate students have given presentations and organized sessions at national and international meetings of various scientific organizations. These include the Society for Risk Analysis annual meeting, EPA Conference on Envi-



ronmental Statistics and Information, the Joint Statistical Meetings, and Environmetrics. A detailed list of presentations is given in Appendix C.

2.5 Educational activities

During the 1998-1999 academic year, NRCSE supported the development of “The TRUTH about Science.” This is a 5th-8th grade scientific research curriculum that guides students through the process of conducting scientific research: asking a testable research question, designing and conducting an independent field project, organizing and analyzing data, and presenting results as both poster and oral presentations. The curriculum is composed of 40 individual lessons, which are available at the NRCSE web site <http://www.nrcse.washington.edu/resource/curriculum/truth.asp>. About half of the lessons are stand-alone lessons to teach basic research skills such as developing hypotheses, setting up controls, random selection of observations, calculating an average and a t-statistic, and graphing data. The other half of the lessons apply the concepts to the Long-Term Research Project (LTRP). Students work in groups to design and carry out their own LTRP. For example, students investigated whether mushrooms in the shade were healthier than mushroom in the sun or whether there were more aphids on red maple versus red alder trees. The curriculum culminates in a celebration night at which students display posters of their research and give 5-minute presentations to their parents and classmates.

The PI for the grant was NRCSE member June Morita. Matching funds were provided by The Discuren Foundation. Kathryn Kelsey, a post-doc in the College of Forest Resources, and Ashley Steel, a graduate student in the Quantitative Ecology and Resource Management program, were employed by the project. They piloted the program in the Fall of 1998 at two Seattle public schools: Decatur Elementary (Alternative Elementary School #2) and Summit K-12. During the Spring of 1999, they polished the lessons and supported two additional teachers in carrying out the curriculum. Through a partnership with the Middle School Science Systemic Change Partnership (MSSSCP), the curriculum was also piloted by two teachers at Blaine School. In August of 1999, The Discuren Foundation supported a second grant to teach a 3-day teacher workshop on “The TRUTH About Science” to middle-school science teachers in the Seattle Public Schools. The workshop was held in cooperation with the MSSSCP. Seattle Public Schools provided substitute teachers so that participants could attend. Eighteen teachers attended the workshop, representing 11 different schools. Kelsey and Steel have recently received a third grant from The Discuren Foundation. The third grant will be dispersed through the Alliance for Education and will fund the dissemination of the curriculum, including updating and maintenance of the web page (which will continue to be housed at NRCSE), follow-up with teachers who have used the curriculum in their classrooms, curriculum revisions



based on teacher feedback, a second teacher workshop, and investigation of publication opportunities.

In conjunction with this project, the first set of posters from Decatur and Summit were submitted to the American Statistical Association Poster Competition. In addition, a panel of local statisticians judged the posters, and NRCSE awarded prizes to the best ones.

2.6 Professional service and recognition

Paul D. Sampson was awarded the Distinguished Achievement Medal of the American Statistical Association Section on Statistics and the Environment.

Loveday Conquest, Peter Guttorp, and Jim Karr were among the recipients of twentieth century distinguished service awards at the Ninth Lukacs Conference in Bowling Green, OH, for contributions to the synergistic development and direction of statistics, ecology, environment and society.

June Morita received the University of Washington Distinguished Teaching Award. She is the fourth Center member to receive this honor. Previous NRCSE recipients are Loveday Conquest, Gerald Van Belle, and David Madigan.

David Ford participated in the EPA Science Policy Council Model Acceptance Criteria and Peer Review White Paper Working Group which produced the document “White Paper on the Nature and Scope of Issues on Adoption of Model Use Acceptability Guidance.” Paul Sampson and Alison Cullen participated in peer reviews for the U.S. EPA, Health Canada and Environment Canada.

Alison Cullen has been commissioned by the Society for Risk Analysis to write a white paper entitled “Risk and Uncertainty: Quantitative and Precautionary Approaches” for their Year 2000 Symposium on Risk Analysis. The Symposium will be held in June 2000 and will focus on the discussion of 10 white papers on all aspects of Risk Analysis, Risk Management and Decision Making.

Peter Guttorp is a member of the Scientific Advisory Board of the recently awarded EPA Northwest Particulate Matter Center at the University of Washington, and is also a Senior Statistical Adviser for the PM Center. He is also a member of the Science Advisory Council for the Geophysical Statistics Project at the National Center for Atmospheric Research in Boulder, Colorado.

Loveday Conquest is the current Chair of the American Statistical Association Section on Statistics and the Environment. June Morita is Chair-elect of the American Statistical Association Council of Chapters. Adrian Raftery continues as Applications Editor of the



Journal of the American Statistical Association. Alison Cullen is a Council member of the Society for Risk Analysis.

2.7 Other

NRCSE is co-sponsoring the Student Paper Awards of the American Statistical Association Section on Statistics and the Environment. This co-sponsorship was motivated by a desire to ensure that awardees would be able to attend and participate in the Joint Statistical Meetings where the award is presented, something that had not previously been assured.

The Center publishes a newsletter about four times a year, with the latest developments, publications, and other items of potential interest to the membership. The newsletters are available at <http://www.nrcse.washington.edu/newsletter/newsletter.asp>.

3. Research activities

3.1 Internal funding

The internal NRCSE research funds are allocated annually by the Executive Committee after a competitive application process. Criteria for awards include

- * Scientific merit.
- * Relevance to the Center's agenda.
- * Evidence of involvement by EPA scientists.
- * Feasibility of project and likelihood of substantial products.
- * Results and EPA contacts of previous NRCSE support

3.1.1 Ranked set sampling: costs and applications

Center member: Loveday L. Conquest

EPA collaborator: Barry Nussbaum

W ESTAT collaborator: David Marker

Research assistant: Nicolle Mode

Ranked set sampling (RSS, McIntyre 1952) is a two-phase sampling procedure that reduces the number of samples required from a more exacting and expensive measurement by using expert knowledge or other frugal measurement to select the sampled values. Current work is focusing on [1] generalizing the cost analyses to unbalanced designs (i.e. unequal set sizes where each order statistic appears an unequal number of times), and [2] other sampling schemes where the initial data are not just ranked, but also placed in strata based upon expected ranges (double sampling with cutpoints).



The paper submitted last year to *Environmetrics* (Ranked Set Sampling for Ecological Research: Accounting for the Total Costs of Sampling, by Mode, Conquest, and Marker) has been published (Vol. 10, pp. 179-194). Another manuscript, “When Can Ranked Set Sampling Best Be Used?—Issues of Application,” is being prepared for submission to *Ecological and Environmental Statistics*.

In September, 1999, Nicolle Mode and Loveday Conquest met with NRCSE visitors Bimal Sinha (U. Maryland Baltimore) and Barry Nussbaum for two days to discuss collaborative research. Areas for collaborative research include extending the cost ratio inequality for unbalanced ranked set samples, and for the case where the interest is on estimating a quantile of interest (rather than the population mean). Known distributions can be investigated (e.g., normal, exponential) in addition to a distribution-free approach.

3.1.2 Assessment of deterministic models

Center members: David Ford and Joel Reynolds

Research assistant: Marianne Turley

During the year we concentrated on three activities:

We developed software implementing an evolutionary computation algorithm for the solution of the Pareto frontier, i.e., the set of parameterizations for a model that satisfy a number of model output criteria. A critical requirement for evolutionary computation is that it makes a comprehensive search of the parameter space and at the same time approaches solution nodes closely. In classical optimization mathematical methods have been used to define how searches are made, but in evolutionary computation for the Pareto frontier such an approach is not available. In practice what is required is that the repeated “breeding” of new parameterizations must combine refinement to individual solution nodes with maintaining some parameterizations that explore the complete space for new solution nodes. Our new software improves on previous work by changing the rates of parameter mutation and parameter cross-over in successive generations of parameterizations. The program was fully commented ready for general release.

We continued to build experience in the use of Pareto Optimality in the assessment of deterministic models by testing multiple outputs of models. For many environmental and ecological models it is likely that there can never be an absolute assurance that the optimum set of parameterizations has been defined. Consequently, at this stage in the work, it is particularly important to test the Pareto Optimality procedure against systems where solutions are obtained with different techniques and where data can be constructed with known characteristics. We have completed such an exercise, solving for the parameters of bimodal distributions and comparing against parameters used in simulating the test distributions and against other forms of calculation of the parameters.



We organized a joint EPA/NRCSE workshop on Quality Assurance for Environmental Models in September 1999 (see [sec. 2.3.3](#)). The workshop was attended by some 50 people from universities, EPA and other state and federal government agencies.

3.1.3 Statistical modeling of censored data

Center member: Mary Lou Thompson

Research assistant: Kerrie Nelson

We have developed maximum likelihood and semiparametric approaches to point and interval estimation for multiple linear regression in the presence of interval and left censoring. The methodology has been implemented in Splus and a program for general implementation is being developed for web access. We are currently evaluating and comparing the characteristics of the estimates under different assumptions as to the degree of censoring, strength of correlation and sample size.

3.1.4 Statistical adjustment of ozone for meteorological variables

Center members: Mary Lou Thompson, Joel Reynolds, Peter Guttorp, and Paul Sampson

EPA collaborator: Larry Cox

Research assistants: Barnali Das and David Caccia

A review paper on meteorological adjustment of ozone (NRCSE TR 26) was written and submitted to *Atmospheric Environment*. The paper is currently under revision. In conjunction with this work, several of the approaches suggested in the literature have been applied to Chicago ozone data from the AIRS database for the period 1981-1991. The work highlights the need for development of techniques for extreme value analysis of space-time processes, as well as for analysis of networks designed to measure extreme values of a random field.

3.1.5 Evaluation and development of a stochastic precipitation model

Center members: Jim Hughes, Peter Guttorp

Research assistant: Enrica Bellone

We consider the use of stochastic models of precipitation in assessing climate variability and climate change and in downscaling (doing sub-grid scale simulation) of general circulation models of global climate. Technically, our method involves fitting non-stationary hidden Markov models to sequences of multi-station precipitation data. The states of the



model are identified as "weather states" and daily observations from atmospheric fields drive the transitions between weather states.

Current work focuses on developing a model for precipitation amounts in Washington State, using a small network of 10 stations. Issues of sensitivity to measurement error, particularly for small precipitation amounts, are important and difficult. The choice of the number of weather states is another technically challenging question. The work has resulted in a paper (NRCSE TR 21) accepted for publication in *Climate Research*.

3.1.6 Statistical aspects of setting and implementing environmental standards

Center members: Peter Guttorp, Paul Sampson, and Mary Lou Thompson

EPA collaborator: Larry Cox

Research assistant: David Caccia

The typical environmental standard is what may be called an ideal standard. Based on various health effects studies, a target value not to be exceeded is determined, and the standard may be that this value not be exceeded, or only be exceeded with a certain probability, or a certain number of times per year.

Our current work in this project is focusing on analyzing the statistical properties of the present US ozone standards, and developing alternative, statistically more appropriate, implementations of ideal versions of the present standards. This in turn leads to considerations of how to implement with given statistical tolerances an ideal standard, as well as issues of spatial representativeness of networks. A draft paper is under revision, and is expected to be submitted for publication during next year.

3.1.7 Graphical modeling of factors influencing benthic populations in streams

Center members: Thomas Richardson, Peter Guttorp

Research assistant: Florentina Bunea

In order to develop ecologically and statistically sound measures of water quality, a variety of metrics of biological activity and composition as well as of human development have been proposed. In this work we apply recent tools from the theory of graphical modeling to study the dependence structure of those measures that are included in Karr's Index of Biotic

Integrity (IBI). The resulting pictorial representation of the relationships between the component metrics and environmental covariates makes it possible to judge which com-



ponents carry information about different aspects of the stream biology, and which biological measures are most sensitive to specific human activities. The work will result in an NRCSE technical report.

3.1.8 Nonhomogeneous global covariance estimation

Center members: Peter Guttorp, Paul Sampson, and Tillman Gneiting

NCAR collaborator: Doug Nychka

Research assistant: Barnali Das

While isotropic covariance structures on a sphere are well understood, there has been little work on anisotropy. We study anisotropies that occur in atmospheric variables, at least partly related to the rotation of the Earth. Such covariance structures can be developed by deforming the globe (a sphere with a natural orientation) into itself, with an isotropic covariance applied to the deformed globe. A parametric description of the deformation is combined with a likelihood approach to estimate the covariance for global temperature data, characterized by measurement stations coming and going according to the vagaries of national policies in different parts of the world.

3.1.9 Trend estimation using wavelets

Center members: Don Percival, Peter Guttorp

Research assistant: Peter Craigmile

A common problem in the analysis of environmental time series is how to deal with a possible trend component, which is usually thought of as large scale (or low frequency) variations or patterns in the series that might be best modeled separately from the rest of the series. Trend is often confounded with low frequency stochastic fluctuations, particularly in the case of models that can account for long memory dependence (slowly decaying auto-correlation) and non-stationary processes exhibiting quite significant low frequency components. A wavelet approach to estimating trend at a given temporal scale is developed, and procedures for testing the presence of a trend, valid for a large range of assumptions, are proposed. Several technical reports are expected during the coming year.

3.1.10 Global warming and Pacific Northwest snowpack

Center member: Chris Bretherton

UW collaborators: Nate Mantua, Phil Mote

Research assistants: Leslie Bahn, Simon DeSzoeker



We studied the past variation of snowpack in the Washington Cascades and Olympic Mountains and its relation to interannual and interdecadal variations of winter season temperature, precipitation, and atmospheric circulation. We quickly began to collaborate with Nate Mantua and Phil Mote of UW's Climate Impacts Group, who were working on a similar topic. A blend of our work and theirs has been prepared in draft manuscript form, to be submitted (probably in January, as there are still a couple of loose ends and all authors are madly busy) to the *Journal of Climate*.

Our principal findings are as follows. We found that 50% of the interannual variability of snowpack is associated with variations in one circulation pattern that results in a persistently more northwesterly flow over this area. Both temperature variations (5°C peak-to-peak winter mean) and precipitation variations (factor of three variations between extreme winters) contribute almost equally to the historical variability of snowpack. There is significant (20-30%) interdecadal variability in snowpack due to coupling of the snow-producing atmospheric circulation pattern with long-lived sea-surface temperature anomalies in the central north Pacific Ocean. Anthropogenic climate change will likely overwhelm natural climate change by about 2025, with temperature increases of 2°C by 2050 creating snowpack decrease of 50% or more at 1000-1500 m above sea-level and enormous stresses on summertime water supply.

3.1.11 A comparison of SVD and CCA analyses in climate prediction

Center member: J. M. Wallace

Research assistant: Mary Fishel

For her MS thesis, Mary Fishel compared the performance of three different linear statistical techniques for predicting patterns of seasonal mean surface air temperature anomalies over the contiguous United States a season in advance based on knowledge of patterns of sea surface temperature anomalies over the world ocean. One of the methods, canonical correlation analysis (CCA), is in operational use at NOAA's National Centers for Environmental Prediction. Singular value decomposition analysis (SVDA) and redundancy analysis (RA) were the other methods considered in the study. Of the three methods, SVDA is the simplest to apply in practice because it requires the least 'tuning', and CCA is the most involved.

Fishel found that if the sea surface temperature anomalies were assumed to be perfectly known for the season in which the surface air temperature anomalies over the United States were being predicted and if the methods were applied to the data in an a posteriori manner (i.e., without cross validation), CCA and RA outperformed SVDA by a substantial margin. However, when the three methods were applied in a realistic forecast setting in which the sea surface temperature anomalies for the previous season were used to pre-



dict the surface air temperature pattern over the United States, their performance was found to be quite comparable. For all three methods, most of the forecast skill was derived from the El Niño–related sea surface temperature anomalies over the tropical Pacific. These results suggest that the labor intensive tuning required to adapt the CCA methodology to new forecast applications may not be worth the effort. A publication based on Fishel's work is in preparation.

3.1.12 Bayesian methods for assessment of environmental fate and transport models

Center members: Alison C. Cullen, Adrian Raftery

Research assistant: Samantha Bates

The aim of this project is to develop Bayesian methods for assessing uncertainty and variability in risk assessment models. The work this year has focused on the basic methodological framework, and on a one-compartment air-to-soil model developed originally by Alison Cullen for PCBs in the New Bedford Harbor area. The basic methodological framework of Bayesian analysis using induced distributions of the model outputs and the Sampling-Importance-Resampling algorithm is now established. The analysis of the one-compartment model is now almost complete. The project is now moving on to investigate the analysis of two-compartment models (with the air to soil to plant extension of the PCB model as a leading example), and to develop more computationally efficient ways of estimating the required posterior distributions. Two papers have been submitted for publication (Vorhees et al., 1999, and Cullen, 1999), and one methodological and one model assessment paper are expected to be submitted during the coming year.

3.1.13 ORCA: A visualization toolkit for high-dimensional data

Center member: Thomas Lumley

Other investigators: Dianne Cook (Iowa State), Peter Sutherland, and Tony Rossini

A main goal of the Orca project is to make interactive and dynamic graphics programming accessible to researchers from many different backgrounds. It arises from years of research in statistical graphics, and takes advantage of the object-oriented nature of Java to 'open up the data pipeline' allowing developers greater flexibility and control over their applications. The Orca framework separates different aspects of data processing and rendering into segments of a pipeline. New types of dynamic graphics that adhere to a few simple Orca design requirements can easily integrate with existing pipe sections. This integration will allow access to sophisticated linking and dynamic interaction across all Orca view types. Orca pipes can be called from data analysis packages such as Omegahat (an AT&T product) or



R. Considerable effort has been made to facilitate graphical tools for space and time dependent data. The web page for the project is <http://pyrite.cfas.washington.edu/orca>.

3.1.14 Bayesian estimation of nonstationary spatial covariance structure

Center members: Paul D. Sampson, Peter Guttorp

Research assistant: Doris Damian

The approach to modeling nonstationary (or non-homogeneous) spatial covariance structure through a deformation of the geographic coordinate system, as implemented first by Sampson and Guttorp and then by Meiring, has left the calculation of uncertainty in the estimated structure exceedingly difficult using bootstrap methods. We have long recognized the appeal of a formal Bayesian estimation of this spatial covariance model assuming a Gaussian model for the space-time process. We have just completed the first complete specification of a Bayesian estimation paradigm for the spatial deformation model and its implementation using MCMC methods. The computations are still highly demanding, but with attractive benefits for the development of a new Bayesian spatio-temporal estimation (kriging) methodology for environmental monitoring data. In the process of this investigation, a number of results concerning likelihood-related estimation of variograms and spatial deformations have been revealed. The first manuscript from this research will shortly be submitted for publication.

3.1.15 Agricultural modeling for watershed management

Center member: Alison Cullen

EPA Region X collaborators: Chris Feise and Karl Arne

The deliverables of this project are: (i) to build a model using Stella software (by Region X request) to represent agricultural inputs to the environment at the watershed scale level, (ii) to identify the interrelationships between inputs to and outputs of the agricultural system in order to gain a more accurate picture of which are having the greatest impact on watershed-scale ecosystems, (iii) to describe the tradeoffs involved in managing a system via assessment of maximum contaminant loading vs. managing for the overall health of the watershed, and (iv) to make recommendations regarding the prioritization of policy options that will make the most efficient use of limited agency resources.

3.1.16 Particulate matter field study in Slovakia

Center member: Alison Cullen

EPA collaborator: John Vandenberg

Other collaborators: Michael Brauer, UBC, Canada; Eleanora Fabianova, Eva Mikhalikova, Peter Miskovic, Frantiska Hrubya, SUHE, Slovakia.



Recent interest in the levels of and health effects associated with airborne particulate matter exposure have sparked studies in the US and worldwide. Working with local scientists we are examining new measurements of PM_{2.5} taken by personal monitors in occupational settings, both industrial and office type, and in the home, by researchers at the SUHE (Institute for Epidemiology and Hygiene) in Banska Bystrica, Slovakia. This work also involves Michael Brauer at UBC and John Vandenberg at HERL, EPA, and has received funding from the Joint Fund for US/Czech/Slovak Science and Technology. Regression analyses will be carried out in the coming year to identify factors influencing particulate matter exposure in Slovakia and to support the standard setting process.

A workshop in Slovakia is planned for October, 1999 (sec. 5). We have completed a manuscript "Personal Exposure to particles in Banska Bystrica Slovakia" (authors: M. Brauer, F. Hruby, E. Mihalikova, E. Fabianova, P. Miskovic, A. Plzikova, M. Lendacka, J. Vandenberg and A. Cullen) which will be presented at the PM 2000 conference in South Carolina in January, 2000, and submitted to either *Environmental Health Perspectives* or *Exposure Analysis and Environmental Epidemiology*.

3.1.17 Composite sampling

Center member: Gerald van Belle

WESTAT collaborator: David Marker

The Department of Housing and Urban Development and the National Institute of Environmental Health Sciences are sponsoring a national survey of dust hazards in housing. Westat developed the survey and was to conduct the data collection between June and October 1998. The survey assessed children's potential household exposure to lead and allergens by estimating the levels of lead in dust, soil, and paint, the prevalence of hazardous levels of lead, and levels and patterns of allergens in dust in homes. The survey is an area probability sample of 1,000 homes representing the entire U.S. housing stock. The survey collected multiple floor dust samples from every house, all of which were to be measured individually. The dust samples were sent to analytical laboratories for chemical analysis for lead and selected allergens.

NRCSE funded an add-on to generate empirical data on matched individual samples and composites for lead, as follows. After the acid digestion of a sample was completed, extracts from two to four of the floor dust samples from each home in the sample were to be drawn and composited. The composite samples were then to be analyzed for lead. The composited extract would match what would have been obtained if the same four floor samples had been composited in the field. In addition, the two-to-four individual results will still be available.



We have completed much of the data collection. The overall project has had a number of funding problems (not composite related), so the number of primary sampling units (PSUs) has been scaled back from 100 to about 75. The number of PSUs where composite sampling is being done has also been cut back, since some of the PSUs we are not visiting were intended for composites. Currently we have 660 composite samples from 358 homes in 41 PSUs. We had originally budgeted to collect 620 composite samples from the same number of homes, in 62 PSUs.

Many homes had a mixture of floor surfaces in the four rooms where the composite is being collected, some smooth surfaces (wood or tile) and some carpeted. Because of the very different recovery rates from wipes on these different surfaces, one would not want to combine wipes into one composite across smooth and carpeted surfaces, thus many homes have two composites, one for smooth surfaces and the other for carpeted surfaces. The number of wipes in a single composite can vary from 1-4, with the total number of wipes per home remaining at 4.

The laboratory will finish the assays of the composite samples by the end of January 2000. At that time the statistical analysis will be started. The sampling and statistical analyses were conducted on a random subsample of 620 homes of the 1000 homes. The subsample is an area probability sample representing the entire U.S. housing stock.

3.1.18 Toxicodynamic models for model toxicant-induced developmental toxicity in rodents

Center members: Rafael Ponce and Elaine Faustman

EPA collaborators: Woody Setzer, Chris Lau

UW Collaborator: W. C. Griffith

Research assistants: Tom Lewandowski, Julia Hoeft and Scott Bartell

This project has focused on developing toxicodynamic models for developmental toxicity. A basic premise of this work is that toxicant induced changes in cell proliferation and differentiation can explain adverse developmental effects for several types of model developmental toxicants. Developmental toxicants of interest to this project include environmental agents such as methyl mercury and arsenic as well as example toxicants such as 5-fluorouracil (5-FU), a cancer chemotherapeutic agent with proven teratogenic potential.



In collaboration with Drs. Setzer and Lau US EPA, HERL, we have been evaluating the extensive toxicological database that they have generated on the developmental toxicity of 5-FU. As reported in last year's progress report a key focus of our work on this compound has been on collection and analysis of their 5-FU limb data. Using that data we were able to define preliminary parameters for a modified Leroux et al (1996) toxicodynamic model. These critical assessments indicated the need for additional characterization of the biologically based parameters as estimates for predicted limb cell impacts in the presence and absence of the toxicant 5-FU did not match our estimates of cell number predicted from their indirect measurements of total protein content.

The main biochemical mechanism for the toxicity of 5-FU lies in its inhibitory effect on thymidylate synthetase (TS) required in the S-phase synthesis (Shuey et al., 1994). Without available information on how 5-FU changes cell cycling rate, we assume that overall cell cycle retardation by 5-FU is solely attributed to the effects observed in the S-phase. Thus, we assumed that a 50% increase in the proportion of cells in the S-phase would result in a corresponding 50% decrease in the cell population reaching a new G1/G0 phase. Based on these assumptions and recent data provided by Dr. Setzer on the effects of 5-FU on cell cycle distribution in embryonic hindlimb, we calculated the observed fraction of cells cycled by 48 hours. We are (with assistance of a first year graduate student, Julia Hoeft) working on a sensitivity analysis to refine these parameters.

In addition to these efforts on 5-FU, we will also be evaluating other model toxicants. Julia Hoeft (in collaboration with Tom Lewandowski and Scott Bartell) will be evaluating solvents (such as ethanol) in this model. These studies are just being initiated.

3.1.19 Integrated exposure and uptake biokinetic lead model (IEUBK)

Center member: Elaine Faustman

UW collaborators: JH Shirai, AC Pierce, and JC Kissel

Research assistant: Scott Bartell

The last twenty years have seen the development of numerous models for predicting the kinetics of lead in the human body (US EPA, 1994). These models are necessary because health effects have historically been linked to specific blood lead concentrations, while pollution control and industrial hygiene efforts are most easily directed at environmental (e.g. air, water, soil, and food) lead concentrations. Exposure and toxicokinetic models



provide the quantitative link between environmental concentrations and biomarkers such as blood lead concentration.

EPA requested that the NRCSE review childhood toxicokinetic lead models and suggested additional validation strategies. The agency is particularly interested in validation of its own model, the Integrated Exposure and Uptake BioKinetic lead model (IEUBK), which predicts blood lead concentrations for children ages 0 to 7 years old based on environmental lead concentrations.

One of the most controversial parameters in childhood exposure models is the soil ingestion rate. Experimental estimates are usually determined from tracer studies, in which aluminum, silicon, titanium, and other rare earth elements are measured in the diet, urine, and feces. Steady state conditions are assumed, and mass balance approaches are used to estimate the rate of soil ingestion. Soil ingestion rate estimates derived in these studies vary by several orders of magnitude, appear to fluctuate daily for each monitored individual, and are highly dependent on the tracer and statistical model selected. An alternative to the tracer study is the use of pollutant biomonitoring studies which include environmental measurements. We have obtained data from one such study, the Urban Soil Lead Abatement Demonstration Project (USLADP), in which children's blood lead concentrations were monitored for two years following the replacement of contaminated yard soil with soil with lower lead content. A perturbation analysis was performed using a simplified toxicokinetic lead model to estimate a soil ingestion rate for each child in the USLADP study. The model includes a probabilistic uncertainty analysis component which assesses the impacts of toxicokinetic parameter uncertainty on each child's estimated soil ingestion rate.

Estimates of soil ingestion rates have a mean of 10 mg/day and a 95th percentile of 93 mg/day. Uncertainty regarding individual soil ingestion rates is clearly large and is primarily due to uncertainty in the lead absorption fraction. Model uncertainty is not accounted for in these estimates and would be expected to increase the variance in the individual estimates.

We have recently completed the model runs for this analysis, and are now compiling the results. We have presented these results at an EPA workshop last June. We are preparing a manuscript, "Estimation of soil ingestion rates from observed blood lead loss following soil remediation", for submission to *Environmental Health Perspectives* by January 31, 2000. Results were also presented as "Uncertainty and variability in childhood soil ingestion rates estimated from USLADP blood lead levels" at the International Society for Risk Analysis annual meeting in December 1999.



3.1.20 A linked toxicokinetic-toxicodynamic model of methylmercury-induced developmental neurotoxicity in the fetal rat

Center researchers: Rafael Ponce and Elaine Faustman

UW collaborator: W. C. Griffith

Research assistant: Tom Lewandowski

For risk assessments, there is a need to integrate both exposure information and mechanistic toxicity information to obtain improved risk estimates. Ideally, this requires linkage of both toxicokinetic models describing the absorption, distribution, metabolism and elimination profiles of toxicants with biologically based dose-response models that describe toxic endpoints/effects. In this project we demonstrate how to link a modified toxicokinetic model for methyl mercury with our toxicodynamic model described in [3.1.18](#).

During the last year we have performed simulation testing of model variables to assess model sensitivity. We have examined all model assumptions and variable parameter estimates to determine their impact on model predictions. This analysis demonstrated sensitivity of the model to both the rates of cell division and the assumption of the critical number of cells for proper midbrain functioning. Of interest are refining estimates of the number of starting cells in the GD 12 rat midbrain, estimation of the fraction of cells dividing over GD12-17 (currently assumed to be a constant 55%), refined estimates of cell division over GD12-17, and improved methods for identification of differentiating cells.

To complement the existing toxicodynamic model, Mr. Lewandowski and others have developed a toxicokinetic model to predict maternal and fetal disposition of methylmercury during gestation; this toxicokinetic model is linked with the existing toxicodynamic model. The idea underlying the development of such a biologically based toxicokinetic-toxicodynamic model would be that one could relate a whole body dose, that is delivered by various routes of exposure, to an observable effect on the developing fetus.

The toxicodynamic model describes aspects of the dynamic process of organogenesis, based on Monte Carlo analysis of branching process models of cell kinetics. The toxicokinetic model demonstrates an adequate fit to experimental toxicokinetic data. For example, 3 days after a dose of 1 mg/kg (given on day 12 of gestation), the model predicts brain and blood levels within approximately 10% of the values observed by Wannag (1976). In terms of toxicodynamic effects, the model predicts 15% and 45% decreases in the number of committed neural cells (on gestational day 15, relative to untreated baseline) at fetal brain concentrations of 0.5 and 1.0 mmol/kg. It is anticipated that the exist-



ing model can be extended to address other species (i.e., humans) and other developmental toxicants that act by similar mechanisms (i.e., cell cycle disruption). Preliminary results of these efforts have been presented at the Society of Toxicology Annual Meetings, Society of Risk Analysis and at the upcoming NRCSE/USEPA-LV Statistical Conference in Las Vegas, December 1999.

3.1.21 Temporal fallacies in biomarker based exposure inference

Center researchers: Rafael Ponce and Elaine Faustman

EPA collaborator: Anne Jarabek

UW collaborator: W. C. Griffith

Research assistant: Scott Bartell

Biomarker measurements from single time points are often used to make inferences about longer periods of toxicant intake. However, toxicant exposures rarely, if ever, occur under steady-state conditions, and biomarkers are typically most sensitive to recent toxicant exposures. Moreover, toxicant exposures are typically episodic and vary in magnitude over time. While it is often believed that the error introduced by the steady-state assumption is minimal and can safely be ignored, no rationale is typically presented to support this belief. Moreover, no guidelines have been established for determining a *de minimus* error level or for estimating the degree of error potentially introduced by a fallacious temporal assumption in biomarker interpretation. A framework for evaluating the potential magnitude of temporal fallacy error has been developed along with applications of this framework.

The magnitude of error depends on many factors, including the exposure frequency, exposure magnitude, exposure duration, baseline biomarker value, and exposure inference duration. Graphical presentation of the error as a function of those factors provides insight into the design and interpretation of biomarker sampling programs. In addition, these results can be combined with a stated *de minimus* error level to determine whether or not the potential error introduced by temporal fallacy is acceptable. We developed statistical methods for evaluation of errors in special cases and simulation tools for evaluation of other cases. Application of these methods has been made for a recognized model relating longitudinal mercury exposure to mercury blood and hair concentrations in human adults.

It was found that blood mercury biomarkers are strongly weighted towards the most recent exposures, while hair mercury biomarkers are weighted more toward previous exposures. Temporal error bias increases as the exposure duration decreases and as the exposure inference period increases, and the bias approaches zero with sufficiently long exposure. Blood mercury biomarkers appear to be superior for reflecting the most recent ex-



posures in that they reduce the potential for bias. However, hair mercury may be superior for measuring longer term or historic exposures. While these characteristics are already qualitatively recognized, a statistical approach allows for optimization and adjustment based on the goals of the exposure analysis. These results were presented at the Society for Risk Analysis meeting in December, 1999.

We are currently examining temporal error under less restrictive conditions. Statistical methods for inference based on multiple biomarker samples are of particular interest. We also plan to apply these methods to the analysis of biomarker data sets for mercury and other heavy metals. We are collaborating with Anne Jarabek, NCEA, USEPA and her colleagues on this project and have been asked by her to submit a publication for the special issues of Risk Analysis that she has organized on temporal issues for environmental models. During this next year, she has agreed to participate in our planned NRCSE mini-workshop focused on temporal issues this Spring.

3.2 External funding

NRCSE has considerable funds available for researchers at other institutions. These are used in two different categories: funds for visiting researchers, who spend substantial time at the Center, and funds for subcontracts, where the bulk of the work is done at the researcher's home institution.

3.2.1 Visiting researchers

Name	Organization	Arrival	Departure	Collaborators
Sørensen, Per	Inst Water Env, Denmark	980901	981101	Sampson
Clyde, Merlise	Duke Univ	981001	990715	Guttorp, Sheppard
Cook, Di	Iowa State	981012	981120	Billheimer
Smith, Eric	Virginia Tech	981017	981023	Sampson, Van Belle
Marcus, Allan	EPA	980921	981220	Richardson
Berman, Mark	CSIRO, Australia	990303	990307	Guttorp
Huang, Hsin-Cheng	Academic Sinica, Taiwan	990329	990402	Guttorp, Sampson
Smith, Eric	Virginia Tech	990611	990809	Guttorp, Van Belle
Cook, Di	Iowa State	990614	990718	Billheimer, Guttorp
Nychka, Doug	NCAR	990621	990622	Guttorp, Cook
Nirel, Ronit	Hebrew Univ, Israel	990713	990830	Thompson, Sampson
Nussbaum, Barry	EPA	990929	991003	Conquest
Sinha, Bimal	U. Maryland	990929	991003	Conquest



3.2.2 Particulate matter air pollution

Under separate EPA funding a project on particulate matter air pollution was initiated in 1998. Participants include researchers from Iowa State, Ohio State, NISS, University of British Columbia, Duke, Chapman University and NRCSE. Subcontracts are in place with NISS and UBC ([sec. 4.6.3](#)).

The project has three components: a research arm aiming at producing a special issue of *Environmetrics* during spring of 2000, in time for the scientific assessment of PM air pollution for the revision of the NAAQS; a workshop on particulate matter air pollution ([sec. 2.3.2](#)); and a series of presentations at scientific meetings.

The submitted papers for the special issue of *Environmetrics*, with Peter Guttorp as guest editor, cover a broad range of analyses of particulate matter air pollution.

Clyde: Model uncertainty and health effect studies for particulate matter

Phelan: Timing and Scope of Emission Reductions for Airborne Particulate Matter: A Simplified Model

Cox: Statistical Issues in the Study of Air Pollution Involving Airborne Particulate Matter

Lumley and Levy: Bias in the Case--Crossover Design: Implications for Studies of Air Pollution

Lumley and Sheppard: Assessing Seasonal Confounding and Model Selection Bias in Air Pollution Epidemiology Using Positive and Negative Control Analyses

Dewanji and Moolgavkar: A Poisson Process Approach for Recurrent Event Data with Environmental Covariates

Smith, Davis, Sacks, Speckman and Styer: Air Pollution and Daily Mortality in Birmingham, Alabama: A Reappraisal

Sun, Le, Zidek and Ozkaynak: Interpolating Vancouver's Daily Ambient PM10 Field

Sheppard and Damian: Estimating Short-Term PM Effects Accounting For Surrogate Exposure Measurements From Ambient Monitors.

The issue will also have an editorial addressing the recent court decision regarding the NAAQS for PM and ozone, written by Larry Cox, Richard Smith, Alison Cullen and Peter Guttorp.

A panel discussion on "Understanding particulate matter air pollution" at the Joint Statistical Meetings in Baltimore, MD, in August of 1999 was organized by Peter Guttorp and featured panelists Merlise Clyde, Noel Cressie, Lianne Sheppard, Gerald Van Belle and Jim Zidek.



An invited session on “Statistical Research on Ambient Particulate Matter Pollution” at the TIES/SESS meeting in Athens, Greece, in August of 1999, was organized by Larry Cox, and had talks by Merlise Clyde, Mark Kaiser, and Lianne Sheppard. During the meeting, plans for further cooperative research between NRCSE, Duke and Iowa State were worked out.

Several of the participants in this project will also present papers at the PM 2000 conference in South Carolina in January of 2000.

3.2.3 Ecological assessment of riverine systems by combining information from multiple sources

An NRCSE subcontract with Penn State originated from the NRCSE workshop on combining information from multiple sources in 1997. The co-investigators are Mark Handcock, Penn State, Joe Sedransk, Case Western, and Tony Olsen, EPA Corvallis.

The objective of the project is to improve understanding of the biological integrity of stream and river systems in the United States Mid–Atlantic Region by combining information from separate monitoring surveys, available contextual information on hydrologic units and remote sensing information.

The investigators have constructed and standardized datasets from each of the component surveys. An ARC/INFO database has been constructed containing relevant data from the EMAP Mid–Atlantic Integrated Assessment (MAIA) Stream and River Survey, the Maryland Biological Streams Survey (MBSS), EMAP Mid–Atlantic Landscape Indicators, EMAP Streams network database (RF3), and the USDA Natural Resources Conservation Service soils database. The database has used, where possible, publicly accessible information recently made available through the MAIA Landscape Atlas. The database is compatible with the structure of the Atlas data.

The project is developing spatial statistical models for measures of biotic integrity on the streams and rivers in the MAIA region. The fish metrics at 800 sites from the MBSS survey have been analyzed, and the spatial structure within the Maryland streams described. The model is being extended to the MAIA region, and combined with the much sparser EMAP sites.

The collaboration should ensure that the case study can be interpreted in the context of the MAIA and MBSS studies and easily explored using the standardized data sets available on the WWW.



3.3 Submitted and published research papers

S. M. Bartell and E. M. Faustman (1998): Comments on “An approach for modeling non-cancer dose responses with an emphasis on uncertainty” and “A probabilistic framework for the reference dose(probabilistic R&D).” *Risk Analysis* **18**(6): 663-664.

S. M. Bartell, T. K. Takaro, R. A. Ponce, J. Hill, E. M. Faustman, and G. S. Omenn (2000): Risk assessment and screening strategies for beryllium exposure. *Environment International*, In press.

S. M. Bartell, T. K. Takaro, R. A. Ponce, J. P. Hill, E. M. Faustman, and G. S. Omenn (1999): Risk assessment and screening strategies for beryllium exposure. *Technology*, in press.

S. M. Bartell, Ponce, R. A., Takaro, T. K., R. O. Zerbe, G. S. Omenn, and E. M. Faustman (1999). Risk estimation and value-of-information analyses for three proposed genetic screening programs for chronic beryllium disease prevention. *Risk Analysis*, in press.

S. M. Bartell, T. K. Takaro, R. A. Ponce, J. Hill, E. M. Faustman, and G. S. Omenn (1999): Risk assessment and screening strategies for beryllium exposure. Submitted to Eisenbud Special Issue, *Environment International*.

L. C. Bowling, P. Storck and D. P. Lettenmaier (1999): Hydrologic effects of logging in Western Washington. Submitted to *Water Resources Research*.

E. Bellone, J. P. Hughes and P. Guttorp (2000): A hidden Markov model for downscaling synoptic atmospheric patterns to precipitation amounts. To appear, *Climate Research*.

S. P. Charles, B. C. Bates, P. H. Whetton, and J. P. Hughes (1999): Validation of downscaling models for changed climate conditions in southwestern Australia. *Climate Research* **12**: 1-14.

S. P. Charles, B. C. Bates and J. P. Hughes (1999): A spatio-temporal model for downscaling precipitation occurrence and amounts. To appear, *Journal of Geophysical Research*.

A. C. Cullen (1999): Uncertainty—Lessons from Exposure Analysis. *Inhalation Toxicology* **11**:603-610.

E. M. Faustman and S.M. Bartell (1997): Review of noncancer risk assessment: Applications of benchmark dose methods. *Human and Ecological Risk Assessment* **3**(5): 893-920.



E. M. Faustman, T. A. Lewandowski, R. A. Ponce, and S. M. Bartell (1999): Biologically based dose-response models for developmental toxicants: Lessons from methylmercury. *Inhalation Toxicology* **11**(6): 559-572.

E. M. Faustman (1999): Implications of research for remediation technology design. *Risk Excellence Notes* **1**(9): 9.

E. A. Freeman and E. D. Ford (1999). Effects of data quality on analysis of ecological pattern using the $K(d)$ statistical function. Submitted to *Ecology*.

T. Gneiting (1999): Compactly supported correlation functions. Submitted to *Advances in Applied Probability*.

T. Gneiting (1999): Correlation functions for atmospheric data analysis. *Quarterly Journal of the Royal Meteorological Society* **125**: 2449-2464.

T. Gneiting (1999): Isotropic correlation functions on d-dimensional balls. To appear, *Advances in Applied Probability* **31**.

T. Gneiting (1999): The correlation bias for two-dimensional simulations by turning bands. *Mathematical Geology* **31**: 95-211.

T. Gneiting and Z. Sasvari (1999): The characterization problem for isotropic covariance functions. *Mathematical Geology* **31**: 105-111.

P. Guttorp (2000): Environmental Statistics. To appear, *Journal of the American Statistical Association*.

P. J. Heagerty and T. Lumley (1999): Window subsampling of estimating functions with application to regression models. To appear, *Journal of the American Statistical Association*.

N. R. Hedley, and B. D. Campbell (1998). Collaborative GeoScientific Visualization Project Final Report. Human Interface Technology Laboratory Technical Report R-99-3). Seattle: Human Interface Technology Lab.

N. R. Hedley (1999): Uncertainty in Environmental Research: Beyond Conceptual Difficulties and Synthetic Frameworks. Submitted to *Journal of Risk and Uncertainty*.

N. R. Hedley, C. H. Drew, E. A. Arfin, and A. Lee (1999): Hagerstrand Revisited: Interactive Space-Time Visualizations of Environmental Data. *Informatica*, Vol. **23** (4).



R. C. Henry, E. S. Park, and C. H. Spiegelman (1999): Comparing a new algorithm with the classic methods for estimating the number of factors. *Chemometrics and Intelligent Laboratory Systems* 48, 91-97.

T. A. Lewandowski, S. M. Bartell, C. H. Pierce, R. A. Ponce, and E. M. Faustman (1998): Toxicokinetic and toxicodynamic modeling of the effects of methylmercury in the fetal rat. *The Toxicologist* 42(1-S), No. 683.

T. Lumley and D. Levy (1999): Bias in the Case--Crossover Design: Implications for Studies of Air Pollution . Submitted to *Environmetrics*.

T. Lumley and L. Sheppard(1999): Assessing Seasonal Confounding and Model Selection Bias in Air Pollution Epidemiology Using Positive and Negative Control Analyses. Submitted to *Environmetrics*.

E. S. Park, C. H. Spiegelman, and R. C. Henry (1999), Bilinear estimation of pollution source profiles and amounts by using receptor models. Submitted to *Technometrics*.

E. S. Park, C. H. Spiegelman, and R. C. Henry (1999), Estimating the number of factors to include in a multivariate bilinear model. Submitted to *Technometrics*.

R. A. Ponce, S. M. Bartell, R. C. Lee, T. J. Kavanagh, J. S. Woods, W. C. Griffith, T. K. Takaro, and E. M. Faustman (1998): Uncertainty analysis methods for comparing predictive models and biomarkers: A case study of dietary methylmercury exposure. *Journal of Regulatory Toxicology and Pharmacology* 28(2): 96-105.

E. A. Steel and S. Neuhauser (1999): A Comparison of Methods for Measuring Water Clarity. Submitted to *Journal of the North American Benthological Society*

M. L. Thompson, J. Reynolds, L. H. Cox, P. Guttorp and P. D. Sampson (1999): A review of statistical methods for the meteorological adjustment of tropospheric ozone. Submitted to *Atmospheric Environment*.

D. V. Vorhees , A. C. Cullen, and L. M. Altshul (1999): Polychlorinated Biphenyls in House Dust and Yard Soil Near a Superfund Site. *Environmental Science & Technology* 32:2151-2156.

B. Whitcher, P. Guttorp and D. B. Percival (1999): Wavelet analysis of covariance with application to atmospheric time series Submitted to *Journal of Geophysical Research*.



4. Administration

4.1 Director and Associate Director

The NRCSE director, Peter Guttorp, spent Autumn quarter of 1998 in Sweden, developing contacts with European researchers in environmental statistics (see [sec. 4.6.3](#)). During his absence, Paul Sampson was acting director. Due to the heavy administrative load for the director, the executive committee decided to add an associate director position to the Center administrative staff. This is a 25% position, and Paul Sampson was selected by the executive committee to fill it. The duties of the associate director include maintaining the web sites and other external informational issues and coordinating the visitors program.

4.2 Executive and advisory committees

4.2.1 Executive committee

The executive committee saw the conclusion of two terms of service: Gerald Van Belle and Paul Sampson. In a membership election Mary Lou Thompson (Biostatistics) and Paul Sampson were voted in for three-year terms on the executive committee. Continuing members are Alison Cullen (Public Affairs) and David Ford (Forestry). Much of the work of the executive committee is done via email, although formal decisions and strategic discussions generally require meetings. All meetings are announced with their agendas on the executive committee web page <http://www.nrcse.washington.edu/people/execom.asp>.

4.2.2 Advisory committee

There was no formal meeting of the advisory committee this year. Rather, the director had individual discussions with each of the advisory committee members. Next advisory committee meeting will be in conjunction with an internal planning workshop in January of 2000 (see [sec. 5](#)).

4.3 Members

Four new members were proposed by the membership and elected by the executive committee: Dean Billheimer, Tillman Gneiting, and Thomas Richardson, all assistant professors from the Statistics department, and Rafael Ponce, Research Scientist in Environmental Health. Two members left the University of Washington: Joel Reynolds for the State of Alaska Department of Fish and Game, and David Madigan for AT&T.

4.4 Hiring

Three postdoctoral researchers were hired. Eun Sug Park from Texas A&M, working on receptor modeling, arrived in January. Her contract has been extended through the aca-



demic year 2000-01. Kevin Brand from Harvard University, working on risk analysis, arrived in May. He has since left for a permanent position in Canada. The Departments of Statistics, Mathematics, and Applied Mathematics at the University of Washington were awarded a VIGRE grant from the National Science Foundation, and as part of this grant Pip Courbois from Oregon State was hired as a postdoc. He is expected to arrive in December, and will be housed in NRCSE, while also having teaching duties in the Statistics department.

The applications programmer, Peter Sutherland, left in February for a position in California. Instead of replacing him, the executive committee decided to use these funds for the associate director position ([sec. 4.1](#)).

4.5 Space

The Center was advised by the Provost's office in May of 1999 that our space in Bagley Hall was needed by another unit, and that we would have to find alternative space. No acceptable space was provided by the University administration, and after discussions with the Statistics department, the Center executive committee approved a plan in which the Center was to move into Statistics space. Among the advantages is the proximity both to the Statistics department, its faculty and graduate students, and to the Mathematical Sciences Research Library. The move took place early in the Autumn quarter. While the space situation for the Center currently is adequate, there is serious concern that the Statistics department and its various research groups, including NRCSE, will run out of space in the near future.

4.6 Relations to other statistical research groups

The Center aims at building a national and international network of environmental statistical research. To that effect we cooperate with a variety of other research groups.

4.6.1 NCAR (National Center for Atmospheric Research)

An NRCSE research assistant, Barnali Das, is spending Autumn quarter 1999 at the Geophysical Statistics Project at NCAR working on the development of statistical methods for data collected on a globe ([sec. 3.1.8](#)). This visit is jointly funded by NRCSE and NCAR/GSP. In addition, plans for joint funding of postdoctoral researchers are under discussion, and the two groups are planning a joint workshop on large data sets for the summer of 2000. The organizing committee for this workshop consists of Dianne Cook, Iowa State, David Madigan, AT&T, Chris Wikle, U. Missouri Doug Nychka, NCAR and Peter Guttorp, NRCSE.

4.6.2 NISS (National Institute for Statistical Sciences)

A subcontract with NISS on particulate matter work ([sec. 3.2.2](#)) funded a research assistant to Richard Smith during the summer of 1999.



4.6.3 Other research groups

The Center has a subcontract with Penn State to work on the follow-up from the 1997 workshop on combining data from multiple sources ([sec. 3.2.3](#)). The investigator is Mark Handcock, and the subcontract covers a research assistant.

A subcontract with the University of British Columbia covers particulate matter work ([sec. 3.2.2](#)) under the leadership of Jim Zidek and John Petkau. Other collaborators in this context include Mark Kaiser at Iowa State, Noel Cressie at Ohio State, Merlise Clyde at Duke, and the NISS group mentioned in the previous subsection.

During Guttorp's visit to Europe in Autumn 1998, a collaboration with European Union scientists was initiated. This resulted in a joint proposal "Estimation of human impact in the presence of natural fluctuations" to the European Commission from researchers at University of Linköping (Sweden), Lancaster University (UK), the Finnish Meteorological Institute, The European Commission Joint Research Center (Italy), GKSS (Germany), and ARMINES (France). The proposal was funded at the level of 900,000 euro, and is aimed at creating tools for times series decomposition into meteorologically induced fluctuations and estimates of human impact; significance tests permitting retrospective impact assessment; and model reduction procedures that facilitate merging of statistical and mechanistic approaches. The NRCSE part of the project (receiving no funding from the EU) focuses on the singular value decomposition as a tool for meteorological adjustment of spatio-temporal air quality data (cf. [sec. 3.1.4](#)). The project is directed by Anders Grimvall at University of Linköping, and co-investigators include Hans Wackernagel, Peter Young, Peter Diggle, Ulrich Callies, Peter Guttorp, Jari Walden, and Andrea Saltelli.

5. A view towards the future

On January 20, 2000, the Center is holding an internal workshop. This has a dual purpose: to give Center members, students and postdocs a better understanding of the research being done at NRCSE, and to think about future research projects and, more generally, the future direction of the Center.

Center members will continue to present their work to EPA laboratories. A workshop is scheduled in Las Vegas for December 14-15. We are tentatively discussing a workshop at Research Triangle Park in March. We are hoping that these workshops will help develop stronger ties with individual EPA researchers who are interested in the type of work we are doing, and develop new links and research directions for Center members.

An international workshop on "Exposure Assessment in Environmental and Occupational Health" will take place October 25-26, 1999, in Donovaly, Slovakia. This workshop is co-sponsored by the Slovakia State Health Institute, the US EPA, University of British Columbia, and NRCSE. Alison Cullen, NRCSE, John Vandenberg, EPA, and Michael



Brauer, UBC, are North American members of the planning committee. Currently three other research workshops are in the planning stage. Jointly with NCAR/GSP we are planning a workshop on large data sets in Boulder in July 2000 ([sec. 4.6.1](#)). Jay Ver Hoef, University of Alaska at Fairbanks, and David Higdon, Duke, are planning a workshop at NRCSE in Seattle on spatial moving average models, tentatively scheduled for October 2000. Paul Sampson, NRCSE, is planning a small workshop on monitoring network design. No date has yet been set for this workshop. A teaching workshop, entitled “Statistical Basis of Human Health Assessment,” and aimed at employees of EPA region X and other agencies. The purpose of the workshop, which is organized by Center members Rafael Ponce and Elaine Faustman together with EPA’s Patricia Cirone is to ensure some understanding of the statistical issues underlying risk analysis problems occurring at the EPA.

The NRCSE are sponsoring two invited sessions at the Joint Statistical Meetings in Indianapolis, August 2000. Both are co-sponsored by the ASA Section on Statistics and the Environment. One session is entitled “Modeling heterogeneous spatial covariance” and has David Higdon, Duke, Olivier Perrin, U. Toulouse-I, and Alexandra Schmidt, U. of Sheffield as speakers with Paul Sampson, NRCSE as discussant. The second is entitled “Statistical approaches to the assessment of environmental models”, with speakers Samantha Bates, Peter Guttorp and David Ford, all from NRCSE.

Two Center members, Lumley and Sheppard, form the statistical core of the recently formed EPA Northwest PM Center. We expect to assist the PM Center with methodological developments appropriate to their research projects, and expect to be able to use data collected by them in our research. The two Centers plan to collaborate closely.

We intend to make several pieces of software publicly available during 1999–00. This includes POMAC 1.0 ([sec. 3.1.2](#)), an S-Plus 4.0 port of Doug Nychka’s FUNFIT programs, and software for estimating nonstationary spatial covariance structures ([sec. 3.1.14](#)).

The Center has currently no long-term visitors planned for the academic year 1999–00, but expect at least one full year visitor for 2000–01. A number of short-term visitors are coming. The executive committee will consider a variety of approaches to strengthen the visitors program. In addition, we hope to continue broadening the base of research collaboration through subcontracts and separate grants and contracts.



Appendix A. Seminars

Several of the NRCSE seminars during 1998–99 were videotaped and are available at the Center web page at URL <http://www.nrcse.washington.edu/seminars/nrcse-video.asp>. The Spring quarter seminars were joint with the student seminars of the graduate program in Quantitative Ecology and Resource Management (QERM). The following is a list of seminar presentations during the academic year.

Autumn 1998

Sept 29: Tim Larson, Environmental Science, UW
Smoke, Dust and Haze

Oct 6: Paul Sampson, Statistics, UW
Monitoring Network Design and Air Quality Standards

Oct 13: Per Settergren Sørensen, Institute of the Water Environment, Denmark
Mapping Mussels at the Sea Bottom by Use of Hydroacoustics: Some Advances of Traditional Methods

Oct 20: Kiros Berhane, Department of Preventive Medicine, University of Southern California
Flexible multi-stage modeling of Pulmonary Function in Children

Oct 22: Eric Smith, Virginia Polytechnic Institute (Joint seminar with Biostatistics)
Evaluating Model Goodness of Fit for Complex Environmental Models

Nov 3: Allan Marcus, US EPA
Particulate Matter Measurement Error, Correlation, and Confounding: How Serious a Problem?"

Nov 10: Suresh Moolgavkar, Fred Hutchinson Cancer Research Institute.
Air Pollution and hospital admissions for COPD in King County

Nov 17: Drew Levy, Epidemiology, and Thomas Lumley, Biostatistics, UW
A case-crossover study of air pollution and primary cardiac arrest: challenges and some results'

Nov 24: Francesca Domenici, Biostatistics, The Johns Hopkins University
National Mortality, Morbidity and Air Pollution Study: Statistical challenges



Dec 1: Merlise Clyde, Statistics, Duke University
Does Particulate Matter Particularly Matter?

Winter 1999

January 12: Peter Guttorp, Department of Statistics and NRCSE, UW.
Displaying Uncertainty in Contour Lines

January 19: David Poole, Department of Statistics, UW.
Bayesian Inference for a Non-invertible Deterministic Model for Bowhead Whales

January 26: Jeremy York, Cartia Inc.
Analyzing Textual Data using a Map Metaphor

February 2: Jerry Galt, Hazardous Materials Response Division, NOAA.
Statistical issues encountered when dealing with hazardous materials accidents

February 9: John Yearsley, EPA.
Temperature Inputs of Dams on the Columbia and Snake Rivers

February 16: Brian Mar, Environmental Engineering, University of Washington
Uses and Abuses of Environmental Engineering models

February 23: Ed Rykiel, Washington State University.
Validating Ecological Models: What's Scale Got To Do With It?

March 2: Scott Ferson, Applied Biomathematics.
Why probability is insufficient for handling uncertainty in risk analysis

March 9: Bruce Beck, University of Georgia.
Assuring the Quality of Models Designed to Fulfill Predictive Tasks

Spring 1999

April 6: Eun Sug Park, Research Associate, NRCSE,
Multivariate Receptor Modeling from a Statistical Science Viewpoint

April 13: David Caccia, QERM,
Toward a Method for Design of Air Pollution Sampling Networks

April 20: Mary Fishel, Atmospheric Sciences,



A Comparison of Statistical Methods Used to Predict US Surface Temperatures from
Sea Surface Temperatures

April 27: Kevin Brinck, QERM,
Adding Biological Information on a Multivariate Analysis to Measure Biological
Condition

May 4: Alison Cullen, Public Affairs,
Elicitation and Calibration

May 11: Enrica Bellone, Statistics,
A Hidden Markov Model for Downscaling Synoptic Atmospheric Patterns to Pre-
cipitation Amounts

May 18: Susan Crane Lubetkin, QERM,
Improving Age Estimates of Bowhead Whales

May 25: Kevin Brand, Research Associate, Environmental Health,
Interpreting Bioassays for Policy: Simulating Calibration

June 1: Heather Caffoe, QERM,
Describing and Modeling Early Growth in Managed Stands of Douglas-Fir

Summer 1999

July 1: Ta-Hsin Li, Statistics and Applied Probability, University of California, Santa
Barbara
Multiscale Representation and Analysis of Spherical Data by Spherical Wavelets



Appendix B. Technical reports 1998-99

TRS number 33

Interpolating Vancouver's Daily Ambient PM10 Field

Li Sun, James V. Zidek, Nhu D. Le and Haluk Ozkaynak (Submitted to *Environmetrics* 1999)

TRS number 32

Environmental Statistics

Peter Guttorp (To appear, *Journal of the American Statistical Association* 2000)

TRS number 31

Bias in the Case--Crossover Design: Implications for Studies of Air Pollution

Thomas Lumley and Drew Levy (Submitted to *Environmetrics* 1999)

TRS number 30

Assessing Seasonal Confounding and Model Selection Bias in Air Pollution Epidemiology Using Positive and Negative Control Analyses

Thomas Lumley and Lianne Sheppard (Submitted to *Environmetrics* 1999)

TRS number 29

Timing and Scope of Emission Reductions for Airborne Particulate Matter: A Simplified Model

Michael J. Phelan (Submitted to *Environmetrics* 1999)

TRS number 28

A Poisson Process Approach for Recurrent Event Data with Environmental Covariates

Anup Dewanji and Suresh H. Moolgavkar (Submitted to *Environmetrics* 1999)

TRS number 27

Model Uncertainty and Health Effect Studies for Particulate Matter

Merlise Clyde (Submitted to *Environmetrics* 1999)

TRS number 26

A review of statistical methods for the meteorological adjustment of tropospheric ozone

Mary Lou Thompson, Joel Reynolds, Lawrence H. Cox, Peter Guttorp and Paul D. Sampson (Submitted to *Atmospheric Environment* 1999)

TRS number 25

Meteorological Adjustment of Chicago, Illinois, Regional Surface Ozone Observations with investigation of Trends



Joel H. Reynolds, David Caccia, Paul D. Sampson, Peter Guttorp (1999)

TRS number 24

Wavelet analysis of covariance with application to atmospheric time series

Brandon Whitcher, Peter Guttorp, Donald Percival (Submitted to *Journal of Geophysical Research—Atmospheres* 1999)

TRS number 23

A Comparison of Methods for Measuring Water Clarity

E. Ashley Steel, Steve Neuhauser (Submitted to *Journal of the North American Benthological Society* 1999)

TRS number 22

Examination of U.S. Environmental Regulatory Criteria for Ozone from a Statistical Perspective

Lawrence H. Cox (*Proceedings of the ISI, Helsinki* 1999)

TRS number 21

A hidden Markov model for downscaling synoptic atmospheric patterns to precipitation amounts

Enrica Bellone, James P. Hughes, Peter Guttorp (To appear, *Climate Research* 1999)

TRS number 20

Identifiability for Non-Stationary Spatial Structure

Olivier Perrin and Wendy Meiring (To appear, *Journal of Applied Probability* 1999)

TRS number 19

Bilinear estimation of pollution source profiles in receptor models

Eun Sug Park, Clifford H. Spiegelman, Ronald C. Henry (Submitted to *Technometrics* 1999)

TRS number 18

Operational Evaluation of Air Quality Models

Peter Guttorp and Paul D. Sampson (Novartis Foundation 1999)

TRS number 17

Ranked Set Sampling for Ecological Research: Accounting for the Total Costs of Sampling

Nicolle A. Mode, Loveday L. Conquest and David A. Marker (In press, *Environmetrics* 1999)



Appendix C. Conference presentations

Oct. 1998 P. Guttorp: Using non-stationary hidden Markov models to downscale general circulation models. Zürcher Kolloquium über anwendungsorientierte Statistik. ETH, Zürich, Switzerland.

Oct. 1998 P. Guttorp: State-space models for species compositions. Seminar für Statistik, ETH, Zürich, Switzerland.

Nov. 1998 P. Guttorp and J. Morita: Case-based teaching in statistics and business. Univ. of Stockholm, Depts. of Statistic and Mathematical Statistics, Sweden

Nov. 1998 P. Guttorp: Some research topics in environmental statistics. Dept. of Statistics, Univ. of Linköping, Sweden.

Dec. 1998 P. Guttorp: Some research topics in environmental statistics. Dept. of Mathematical Statistics, Univ. of Lund, Sweden.

Dec. 1998 P. Guttorp and T. Polfeldt: Displaying uncertainty in contour lines. Dept. of Statistics, Univ. of Stockholm, Sweden

Dec. 1998 P. Guttorp: State-space models for species compositions. Dept. of Mathematical Statistics, Univ. of Stockholm, Sweden.

Dec. 1998 A. Cullen and C. Bretherton: Developing Distributions of Annual Average Concentration with Dependency among Daily Values. Society for Risk Analysis annual meeting, Phoenix, AZ.

Dec. 1998 S. Bates: A Bayesian Approach to Assessing Exposure to PCBs in New Bedford Harbor. Society for Risk Analysis annual meeting, Phoenix, AZ.

Dec. 1998 F. Hruha: Personal Exposure to Particles and NO₂ in Banska Bystrica, Slovakia. Society for Risk Analysis annual meeting, Phoenix, AZ.

Dec. 1998 S. B. Curtis: An index of harm for exposure to a combination of radiation and chemical pollutants. Society for Risk Analysis Annual Meeting, Phoenix, AZ.

Dec. 1998 E. M. Faustman: New Approaches to Temporal Issues in Human Health Risk Assessment. Society for Risk Analysis Annual Meeting. Phoenix, AZ.



Dec. 1998 R. C. Lee: The value of biomarker information in aflatoxin risk management. Society for Risk Analysis 1998 Annual Meeting. Phoenix, AZ.

Feb. 1998 C. Bretherton: Northwest Mountain Snowpack, the Pacific Decadal Oscillation, and Implications for Regional Climate Change. Pacific Northwest Climate Workshop, Seattle, WA.

Mar. 1999 N. Hedley: Exploring Cognitive Domain Structures of Geographic Visualization in Multidimensional Space: Perturbing Synergetic Stability with Uncertainty. Association of American Geographers Annual Meeting. Honolulu, HI.

Mar. 1999 N. Hedley, C. H. Drew, E. A. Erfan, and A. Lee: A Space-Time Trajectory of 100-K Area Workers at Hanford. Association of American Geographers Annual Meeting, Honolulu, HI.

Mar. 1999 N. Hedley, T. L. Nyerges, C. H. Drew, and C. Hendricksen: Empirical Research Strategies for Investigating Risk Evaluation with Stakeholder Participation at Hanford. Association of American Geographers Annual Meeting, Honolulu, HI.

Apr. 1999 A. Raftery: Statistical inference for deterministic simulation models. H. O. Hartley Memorial Lecture, Texas A&M University.

May 1999 P. D. Sampson: Sampling and Monitoring: Network Design and Air Quality Standards. HSSS/SPRUCE 99 Workshop: Complex Models and Methods for Environmental Problems, Willersley Castle, UK.

May 1999 S. Bates, A. Raftery and A. Cullen: Bayesian Model Assessment. EPA Conference on Environmental Statistics and Information, Philadelphia, PA.

May 1999 M. L. Thompson: Statistical modeling of multiply censored data. EPA Conference on Environmental Statistics and Information, Philadelphia, PA.

May 1999 P. Craigmile: Trend estimation using wavelets. EPA Conference on Environmental Statistics and Information, Philadelphia, PA.

May 1999 J. Reynolds: Meteorological adjustment of ozone. EPA Conference on Environmental Statistics and Information, Philadelphia, PA.

May 1999 R. Ponce: Development of a linked pharmacokinetic-pharmacodynamic model of methylmercury induced developmental neurotoxicity. EPA Conference on Environmental Statistics and Information, Philadelphia, PA.



- May 1999 M. Turley: Pareto optimal multi-criteria model assessment. EPA Conference on Environmental Statistics and Information, Philadelphia, PA.
- May 1999 D. Marker, WESTAT: Sample designs for environmental data collection: Ranked set sampling and composite sampling. EPA Conference on Environmental Statistics and Information, Philadelphia, PA.
- May 1999 P. D. Sampson: Monitoring network design with applications to regional air quality. EPA Conference on Environmental Statistics and Information, Philadelphia, PA.
- May 1999 S. M. Bartell: Human variability in steady state blood-to-hair, blood-to-intake, and hair-to-intake ratios for mercury: Implications for health risk assessment. Poster. 5th International Conference on Mercury as a Global Pollutant. Rio de Janeiro, Brazil.
- June 1999 P. Guttorp: Stochastic modeling using hidden Markov models. Statistical Society of Canada annual meeting, Regina, Canada.
- June 1999 S. M. Bartell: Estimation of childhood soil ingestion rates using a probabilistic toxicokinetic model and lead biomonitoring data. Presentation and Poster. US EPA Workshop on Lead Model Development: Probabilistic Risk Assessment and Biokinetic Modeling, Research Triangle Park, NC.
- July 1999 M. L. Thompson: Statistical modelling of multiply censored data. International workshop on statistical modelling. Graz, Austria.
- Aug. 1999 E. Park: Statistical science for receptor modeling. Joint Statistical Meetings, Baltimore, MD.
- Aug. 1999 L. Conquest, N. Mode and D. Marker: Climbing over slippery rocks and fallen trees: statistical points to ponder while sampling streams. Joint Statistical Meetings, Baltimore, MD.
- Aug. 1999 L. Sheppard: Modeling Short-Term Air Pollution Health Effects Using Surrogate Exposure Measurements from Ambient Monitors. TIES/SSES meeting (ISI satellite), Athens, Greece.
- Aug. 1999 P. Guttorp: Picture the Future—graphical innovation in environmental statistics. Hunter lecture, TIES/SSES meeting (ISI satellite), Athens, Greece.
- Sep. 1999 A. Raftery: Statistical Inference for Deterministic Simulation Models: The Bayesian Melding Approach. Clifford C. Clogg Memorial Lecture, Penn State University.



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Appendix D . Workshop agendas

D1. NRCSE/EPA workshop at Corvallis EPA

9:30 Peter Guttorp, Director of NRCSE:
Overview of the Center

10:00 Loveday Conquest, Professor, Fisheries:
Integrating judgment into ecological sampling

10:40 Ashley Steel, Graduate student, Quantitative Ecology:
In-stream factors controlling juvenile chinook migration

11:20 David Ford, Professor, Forest Resources:
Multi-criteria assessment of ecological process models

1:30 Dennis Lettenmaier, Professor, Civil Engineering:
Hydrologic effects of logging in Western Washington

2:10 Dean Billheimer, Assistant Professor, Statistics:
Measures of environmental quality and compositional data

2:50 Peter Guttorp, Professor, Statistics:
Graphical modeling as a tool to study the components of the IBI

D2. Particulate Methodology Workshop

October 19 (Monday)

Evening session chair: Tim Larson (Univ of Washington)

7:00 pm Physical and Chemical Characteristics of Atmospheric
 Particulate Matter
 Glen Cass (Cal Tech)

7:50 pm Instrumentation and Measurement
 Candis Claiborn (Washington State Univ)



October 20 (Tuesday)

Morning session chair: Clare Weinberg (NIEHS)

8:40 am Design Considerations for Air Pollution Exposure Effect
 Studies
 Lianne Sheppard (Univ of Washington)
 Discussant: David V. Bates (Univ of British Columbia)

10:30 am Modeling Vancouver PM Fields for Health Impact Analysis
 Jim Zidek (Univ of British Columbia)
 Discussant: Mark Kaiser (Iowa State)

Evening session chair: Phil Hopke (Clarkson Univ)

7:00 pm Meteorology and Particle Transport
 Jason Ching (NOAA/EPA)

7:50 pm Source Apportionment
 Ron Henry (Univ of Southern California)

October 21 (Wednesday)

8:30 am Working group reports and discussion

Morning session chair: Gerald van Belle (Univ of Washington)

9:15 am Statistical Approaches to Handling Exposure Measurement
 Error in the Children's Health Study
 Kiros Berhane (Univ of Southern California)

11:00 am Models for Improved Exposure Quantification
 Haluk Ozkaynak (U.S. EPA)
 Discussant: Paul Switzer (Stanford)

Evening session chair: George Thurston (NYU)

7:00 pm Health Effects of Air Pollution: "Particles in the Air: Guilty as



Charged?"
Joe Mauderly (Lovelace Respiratory Research Inst)

7:50 pm Regulatory Issues
Terence Fitz-Simons (U.S. EPA)

October 22 (Thursday)

8:30 am Working group reports

Morning session chair: Jerry Sacks (NISS)

9:15 am Single Pollutant Effects in Multiple Pollutant Data
Suresh Moolgavkar (Univ of Washington)
Discussant: Arden Pope (BYU)

11:00 am Assessment of Statistical Models
Merlise Clyde (Duke Univ)
Discussant: Adrian Raftery (Univ of Washington)

12:30 pm Conference summary
Larry Cox (U.S. EPA)

D3. Quality Assurance of Environmental Models

Tuesday, September 7, 1999

Defining the problems of Model Assessment and Quality Assurance

Session Chair: Tom Barnwell

8:45am Naomi Oreskes, Department of History, University of California,
San Diego
Model Assessment: Where Do We Go From Here?

9:30am David Ford, College of Forest Resources and NRCSE,
University of Washington
Defining Similarities and Differences in Quality Assurance Requirements
for Classes of Environmental Models



- 10:45am Ray Whittemore, National Council of the Paper Industry for Air and Stream Improvement, Inc.
EPA's BASINS MODEL - Is it good science or serendipitous modeling?
- 11:30am Jan Rotmans, International Centre for Integrative Studies (ICIS), Faculty of General Sciences, Maastricht University
Uncertainty in Integrated Modeling: a Multi-Perspective Approach
- 12:15pm Robin L Dennis, Atmospheric Sciences Modeling Division, US Environmental Protection Agency
Facing Prediction and Multimedia Modeling, Model Evaluation is a Science
and Knowledge Task: Recommendations from Air Quality Modeling
- 2:00pm Iris Goodman, Landscape Ecology Branch, National Exposure Research Laboratory, EPA Las Vegas
Ecological modeling to assess the effect of land cover on water resources:
A
summary of approaches and modeling issues
- 2:30pm William McDonnell, EPA Chapel Hill
Exposure-Response Modeling of Ozone-Induced FEV1 Changes in Humans: Effects of Concentration, Duration, Minute Ventilation, and Age.

Wednesday, September 8, 1999

Development of Methodological and Quantitative Techniques

Session Chair: Peter Guttorp

- 8:30am Andrea Saltelli, Institute for Systems, Informatics and Safety, The European Commission Joint Research Centre
Sensitivity analysis and the quality assessment of environmental models
- 9:10am Adrian Raftery, Statistics and NRCSE, University of Washington
Statistical Inference for Deterministic Simulation Models: The Bayesian Melding Approach
- 9:50am Tony O'Hagan, University of Sheffield
Bayesian Calibration and Model Correction
- 11:00am Joel Reynolds, Statistics and NRCSE, University of Washington
Open Questions in Applying the Pareto Optimal Model Assessment Cycle



11:40am Wendy Meiring, Statistics and Applied Probability, University of California,
Santa Barbara

Thursday, September 9, 1999
Assurance of Models Used in Environmental Regulation

Session Chair: Robin Dennis

- 8:45am David Stanners, Integrated Assessment and Prospective Analysis, European Environment Agency
“Best Available Information” to support European policy making
(what is good enough and sufficient, and how do we get there)
- 9:30am William L. Richardson, ORD, NHEERL, MED-Duluth, Large Lakes Research Station, US EPA
Modeling Quality Assurance Plan for the Lake Michigan Mass Balance Project
- 10:45am Tom Barnwell, Bruce Beck, Lee Mulkey, Environmental Protection Agency, Athens, Georgia
Model Use Acceptability Guidance:
Part 1) Model Validation for Predictive Exposure Assessments: A Draft Protocol
- 11:30am Linda Kirkland, Environmental Protection Agency, Washington D.C.
Model Use Acceptability Guidance:
Part 2) Updating the Protocol for General Agency Use: Stakeholder Input
- 12:15pm Helen Dawson, Superfund Program Support, U.S. Environmental Protection Agency
Evaluating Performance and Reliability of Intermedia Transfer Models Used in Probabilistic Human Health Risk Assessment

Friday, September 10, 1999
The Way Ahead: Linking Research and Practice on Model Assurance

Session Coordinator: Bruce Beck

- 8:45am Discussion Groups
- 11:00am Discussions at the Workshop - A Synthesis



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